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REPORT OF A STUDY SPONSORED BY THE FEDERAL HOUSING ADMINISTRATION TO DEVELOP PRACTICAL DESIGN CRITERIA FOR SEEPAGE PITS AS A METHOD FOR DISPOSAL OF SEPTIC TANK EFFLUENT

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Cincinnati, Ohio

1 May 1963

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Report to
THE FEDERAL HOUSING ADMINISTRATION

Study of
SEEPAGE PITS

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PUBLIC HEALTH SERVICE...ROBERT A.TAFT SANITARY ENGINEERING CENTER

Report of a Study Sponsored by the

Federal Housing Administration

to

Develop Practical Design Criteria for

SEEPAGE PITS

as a Method for Disposal of Septic Tank Effluent

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Details of illustrations in
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studied on microfiche.

May 1, 1963

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FOREWORD

This study, to develop practical design criteria for seepage pits, is one of a series of similar studies conducted for the Federal Housing Administration by the Public Health Service. The series of studies has included the most thorough evaluation ever undertaken of soil absorption systems in actual use. Several thousand families in widespread sections of the country cooperated by supplying information and permitting the examination of systems at their individual homes.

As a result, the FHA Research Program has provided major contributions to the knowledge of soil absorption system design. Facts have been verified leading to positive conclusions concerning the best methods for design and construction of leaching systems within the concepts of present practices. Application of the conclusions will lead to a savings to the homebuilding industry, and in a broader sense to the general public, of many times the actual cost of the studies. It is anticipated these benefits will find application in many other countries as well as in the United States, particularly in underdeveloped areas where disposal of sewage by underground leaching is of even more importance than in the United States.

Above and beyond answers obtained for specific questions, the intensive field investigations have identified important fundamental phenomena governing the use of soil for disposal of sewage effluents. This knowledge can be used as the background for the design of a research program through which even more efficient and economical soil absorption systems might be developed.

Studies concerned with the fundamental behavior of soil are continuing at the Sanitary Engineering Center, and similar investigations are in progress at universities and other research centers throughout the country. Over the past several years the FHA has also sponsored a research program at the University of California, complementing and supplementing the program of the Public Health Service, to investigate chemical, physical, and biological aspects of soil clogging. There has been a frequent interchange of information between the two projects, and Professor P. H. McGauhey, Director of the Sanitary Engineering Research Laboratory at the University of California, has served as one of the four principal consultants on this study. In addition, other reports emanating from all related research activities coming to the attention of the staff have been reviewed and evaluated to check their consistency with the findings described in this report. Immediate improvement in septic tank soil absorption system performance can be achieved by the application of results contained in this report.

CONCLUSIONS

1. Studies covering a wide range of climate, soil, construction methods, and degrees of regulatory control demonstrate that the seepage pit is a feasible device for introducing septic tank effluent from single family residences into the soil in special situations where the pervious soil is deep or where an impervious upper layer is underlaid by a porous stratum.

2. The need for protection of potable ground water may make it necessary to limit the use of seepage pits and other types of leaching systems under some local circumstances.

3. The relationships between absorption area used, soil conditions, and load applied to seepage pits may be expressed by the general equation developed in previous studies on leaching systems as follows:

$$A = \frac{Q}{L} \left(\frac{1}{k} + t \right)$$

where:

A is the amount of absorption area (pit sidewall) used during time, t,

t is the time in service,

k is a soil parameter representing the rate that the soil becomes clogged,

L is a soil parameter representing the volume of liquid that the soil can ultimately absorb,

Q is a loading factor which includes several subfactors such as the characteristics of sewage generated in the home, the amount of treatment given to the sewage both in the septic tank and in the soil absorption system before liquid comes into contact with the soil, the number of persons using the system, and the total volume of liquid discharged to the system.

4. Empirical field observations demonstrate that the general equation can be used to explain performance observed. Specific equations were developed for fourteen soil types which may be used to predict the area required for any design life.

5. Percolation tests in a full scale seepage pit provide a means for determining the amount of absorption area that should be provided under various soil conditions. The empirical relationship, applicable in the range of percolation rates measured of from 0.01 to 0.35 gallons per square foot per minute, may be expressed as:

$$A = 155 - 200 R$$

where:

A is the amount of pit sidewall area (in sq. ft.) that should be provided per bedroom.

R is the average clear water acceptance rate over the full depth of the pit expressed in gallons per square foot per minute.

6. Visual soil ratings based primarily on observed soil texture may provide an alternate means for estimating the needed amount of absorption area.

7. Seepage pits are amenable to modern construction practices and have two main advantages over competitive leaching systems, viz., economy and simplicity of obtaining regulatory control.

8. Seepage pits, as with seepage beds and trench systems, as now constructed and used, undergo a progessive loss of capacity, beginning as soon as the system is put into use. The design criteria developed in this report recognizes this phenomenon and are based on providing sufficient area so that a reasonable period of satisfactory service is nevertheless obtained with a minimum total expenditure for initial upkeep, and replacement costs. Conclusions based on current practice should not be construed to preclude the possibility that improved practice might result in better use of soil for liquid waste disposal. Such benefits would likely accrue from further research designed to follow up the leads suggested by this and other studies. Such research would include the study of such factors as degree and method of sewage treatment, type and size of porous fill, geometry of absorption area, soil chemical characteristics, improved methods of construction to prevent soil damage, and improved methods of applying effluents to soil surfaces.

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BACKGROUND

The seepage pit is a common method of transmitting septic tank effluent into the soil. The most extensive application of the method has been in the western United States; however, pits have been used in significant numbers but on a spotty basis in many states throughout the nation. The term "seepage pit" is sometimes confused with "cesspool" but usually the term "cesspool" means a pit receiving untreated sewage. In some localities a seepage pit may be known as a sump, leaching pit, or dry well. The seepage pit is not a universally acceptable method of waste disposal. Its usefulness is limited, as with all leaching systems, to situations where ground water pollution is not a factor. In some areas the use of seepage pits has been prohibited to prevent potential ground water pollution. The present study has been devoted entirely to the problem of introducing septic tank effluent into the soil. Ground water pollution is a separate subject and this hazard should be evaluated before use of pits is considered.

Seepage pits are also limited to specific soil conditions. They become useful in special situations where the pervious soil is deep or where an impervious upper layer is underlaid by a porous stratum. Construction of seepage pits has been adapted to standardized methods employing modern equipment and has become popular with the building industry. If a soil has been judged suitable, a minimum amount of time for inspection and administrative control is generally required on the part of the control agency.

Even though over-all experience with seepage pit methods seems to have been satisfactory, reports vary from praise to indifference to condemnation. Reasons for differing opinions are elusive, but variations in design, construction, and control have probably accounted for some of the differences of opinion.

Figure 1 is a typical scene illustrating the mass application of seepage pit systems in subdivision housing. The mounds of earth in the background are spoil from the pits. Two pits, approximately 40 feet deep, were provided for each home in this instance. Note the nearness of the houses and the small back yards. This illustrates a common fault of failing to provide sufficient room for system maintenance and space for possible later repair or additions to the system. Use of seepage pits should not be considered as justification for use of small lots.

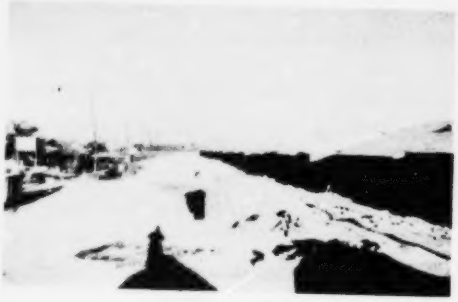


Figure 1
Mass Application of
Seepage Pits

A typical pit is a round hole from 2 to 5 feet in diameter and from 10 to 60 feet deep. Generally a porous lining or a gravel or stone backfill is used to provide structural stability. The hole is usually capped with a brick dome or a concrete slab at a depth of one to four feet below the ground surface. An inlet is provided through the sidewall of the pit or through the cap. Figures 2 and 3 show a newly excavated pit and a pit that has been lined and covered with a brick dome, respectively. Before completion the dome will be covered with a two-inch layer of concrete.

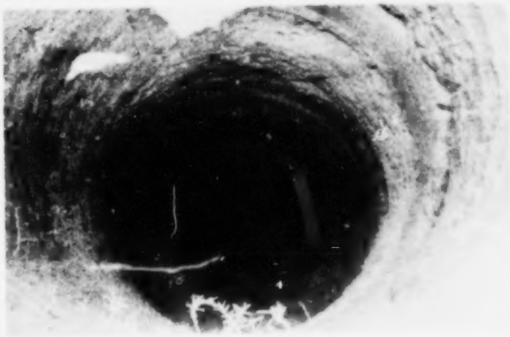


Figure 2

Newly Excavated Pit

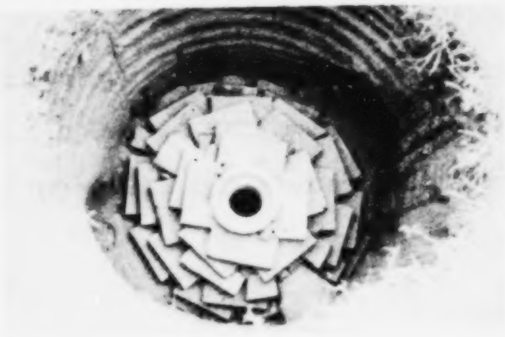


Figure 3

Brick Dome Showing Inlet and Inspection Port

The objectives of this study have been threefold: (1) Determine under what conditions seepage pits are a satisfactory means of disposing of septic tank effluent at individual households. (2) Devise practical tests for judging the suitability of soils for seepage pits. (3) Identify design, construction, and administrative control practices desirable for good pit performance.

METHOD AND PROCEDURE

The general plans for these studies were formulated with the assistance of a board of consultants and members of the Technical Studies Program staff of the Federal Housing Administration. Consultants were selected to obtain expert advice on the nature of the problem, research management, experiment design, analyses of data, and aspects relating to soil. In addition, special consultants have also been used to provide guidance on design and construction of seepage pit systems and to aid in selecting study areas.

All investigations were made in the field to evaluate the performance of systems in actual operation. Gross performance was judged on the basis of years of system service prior to failure. Quantitative performance was judged on the basis of the amount of soil absorption area used in relationship to load applied and time in service.

To select a figure for years of satisfactory service prior to failure, it was necessary to define failure. For the purpose of the study, failure was defined as the inability of the soil absorption system to transmit the daily volume of sewage into the soil in a day's time. A failure was recorded if there was seepage on the ground surface in the vicinity of the seepage pit, or if there was a history of sluggish or inoperative plumbing fixtures and the seepage pit was filled with liquid. In the cases where no failure had occurred, the depth of partial ponding was measured. In all cases the age of the system was established as closely as possible.

In effect, systems in operation under normal conditions serving single-family residences were considered as test installations. In some respects this method was less efficient than a laboratory investigation since laboratory experiments would provide control for such variables as design, care in construction, intensity of use, and climatic conditions. Many of these factors can be identified under field conditions, but large samples are needed to separate their influences. Other factors such as the relative damage to soil during construction, the influence and past history of vegetation, and the influence of different living habits defy accurate measurement, and their effects will always produce variance in the results.

In spite of the apparent inefficiency of the field approach, it was deemed to be more certain to produce usable results in a reasonable length of time. Unlike other factors, time cannot be accelerated. Laboratory experiments up to 5 or 10 years in duration might be required to produce conclusive results. Furthermore, many of the uncontrolled factors producing variance in the field observations cannot be controlled by design or administrative procedures when the results of the study are applied to actual seepage pit construction. Therefore, an estimate of normal variance under the conditions of actual use is an important consideration.

Procedure.

The study was made in cooperation with state and local health departments. A team of investigators composed of a soil scientist, a sanitary engineer, and necessary supporting personnel was stationed at the local health department in each area for a period of several months. In some instances, two trips were made to an area to employ techniques developed subsequent to the initial stay. For the sake of consistency, the same professional personnel conducted the studies at all of the various sites throughout the country. Separate studies were conducted in eight counties located in four states. Table 1 summarizes activities in each of the localities.

Localities for the study were selected after a consideration of the number of seepage pits used, the availability of records, the climate, the type of soil, and the interest of the state and local health departments. Care was taken to select localities which would provide a variety of soil formations and a range in soil textural classes. These aims were fulfilled in the eight counties selected. Soil formations of relatively clean sands were chosen in Jefferson County, Kentucky; Fresno County, California; and Nueces County, Texas. The soil formations in San Diego and Los Angeles Counties, California ranged from silty clay to coarse sand. A similar range in formations was observed in Maricopa County, Arizona. A silty clay formation and variable alluvial deposits were selected in Sacramento and Santa Clara Counties, California, respectively.

In each of the study areas three separate types of investigations were made. An attempt was made to obtain an over-all picture of performance from the records on file at the health department. General surveys were made to determine actual performance at a large group of selected residences. Detailed examinations were made at individual residences to obtain accurate measurements of soil, area, load, and other factors which might influence the useful life of the system.

Table 1

Summary of Field Activities

County and State	Date		Observations	
	From	To	General	Detailed
Jefferson, Kentucky	12-17-56	3-9-57	69	14
Los Angeles, California	1-24-57	6-20-57	61	25
Santa Clara, California	3-15-57	6-21-57	97	21
Sacramento, California	6-21-57	12-11-57	8	27
Fresno, California	6-21-57	12-27-57	184	37
Maricopa, Arizona	12-12-57	7-28-58	237	32
San Diego, California	12-27-57 8-1-58	4-18-58 11-12-58	136	28
Nueces, Texas	2-12-59	4-29-59	53	3
Total			845	187

Review of Records. The principal source of information was the files at the health department, but information was also obtained from the Federal Housing Administration and from septic tank installers. These sources were developed to obtain estimates of the number of systems installed and the number of failures. The records were also of assistance in selecting specific study areas.

General Survey. The purpose and procedure of the general survey underwent a marked evolution as the study progressed. Initially, it was a brief questionnaire designed to substantiate information obtained from the review of records. Upon determining the inadequacy of this approach, the general survey was employed as a supplemental means of locating suitable detailed study sites. Finally, it was reactivated as an essential step in determining area-load relationships.

In its final form the general survey was perfected to give complete information including measurements of system dimensions and construction details. These surveys started with elaborate advance preparation. Working through the health department, plans were publicized in the newspaper. The Better Business Bureau, homeowners' associations, and other appropriate groups were briefed on the operation. Local authorities of cities or villages other than the parent counties were advised, and when appropriate, their permission was obtained before proceeding with the survey. Identification and letters of authority were issued to the surveyors, and plainly marked government vehicles were used in all of the work.

With the aid of available soils information, areas were located where a particular soil formation of interest was predominant. Groups of homes for survey were selected after a consideration of the number of seepage pits, their age distribution, uniformity and price range of houses, and the amount of preliminary information that could be obtained from files. Large subdivisions or areas developed by a limited number of builders proved fruitful from these considerations. Information on suitable subdivisions was sought from sanitarians and inspectors in the health and plumbing departments, FHA offices, builders and builders' associations, and septic tank installers and cleaners.

After a particular area was chosen for further consideration, plats were obtained for subdivisions within the area. System installation dates, street addresses, occupants' names, and dates of occupancy were transferred from the health department and county tax recorder's files to the plats. When health department permits were issued by name instead of address, it was necessary to use old phone books, city directories, and utility records to associate names and addresses. The turn-on and turn-off dates of water and electric companies helped establish the date and record of occupancy. Water meter records were obtained for the life of the house whenever possible.

When all possible preliminary information had been recorded on a separate sheet for each address, a door-to-door survey was initiated to obtain information on family size, living habits, and the record of performance needed to complete the form. Where more than one family had occupied a home, city directories, phone books, and information supplied by neighbors were used to locate the previous residents. If a complete record of occupancy could not be obtained, the system was eliminated from the survey.

After the resident had provided the necessary information, permission was obtained to examine the system. The seepage pit and the septic tank were opened to obtain accurate measurements of dimensions. The depth of effluent in the seepage pit and the depth of scum and sludge at the septic tank outlet were also measured. Figures 4 and 5 show activities at a general survey site. On completing a site the septic tank was cleaned and the homeowner supplied with a description of the system.

Figure 4

Locating Septic Tank and Pit

Figure 5

Taking Pit Measurements

Data from general surveys are handled in a manner similar to life expectancy tables to obtain a picture of failure rate with time in service. In addition, general surveys aided materially in establishing the load-area-time-soil relationship.

Detailed Studies. The basic procedure for detailed studies remained unchanged throughout the study. It was comprised of the general survey procedure plus a comprehensive soils investigation. As shown in Table 1, a total of 187 of these studies was completed in the course of the work. The sites were selected in such a way that at least two detailed studies were made in each soil formation covered by general surveys.

Detailed studies started with an examination of the septic tank. After the tank was opened, the house sewer was checked for obstructions by flushing the toilet and observing the flow into the septic tank.

The depth of sludge and scum was measured in relation to the outlet baffle, and inlet and outlets were checked for obstructions. These precautions were taken to insure that performance of the seepage pit was not unduly affected by malfunctions in the septic tank or sewer.

After determining that the septic tank or sewer conditions had not unduly influenced the operation of the system, the field team then conducted an inspection of the seepage pit and an extensive soils investigation. Complete dimensions of the pit and the depth of ponded liquid were obtained. The type and structural condition of the pit lining and other construction features were determined.

The first phase of the soil investigation was the excavation of a test pit of the same dimensions, and within 6 to 10 feet of the operating pit. Figure 6 shows a field team supervising the digging of a test pit. A log of strata changes and descriptions was recorded as excavation proceeded. An undisturbed core sample and a bulk sample were obtained from each strata.

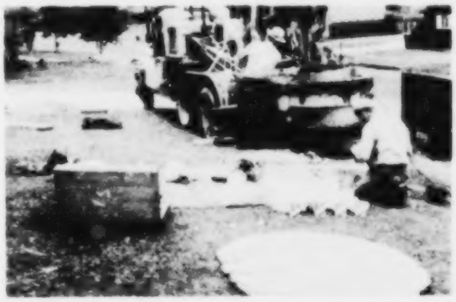


Figure 6
Excavating Test Pit

This test pit was then lined (when necessary) and used to conduct a percolation test. Figures 7 and 8 show two steps in the lining of a pit with concrete rings. The percolation test was conducted by rapidly filling the pit (Figure 9) to the ground surface and then measuring the recession rate. The procedure was repeated three times: twice in succession in one day, and a third time the following day.

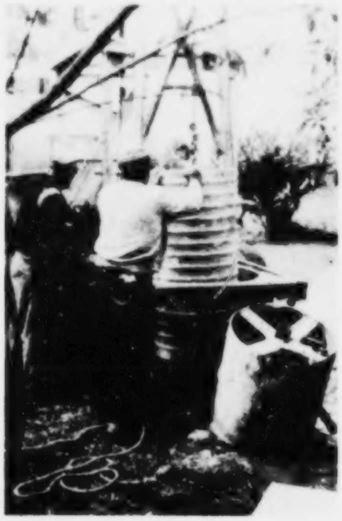


Figure 7

Installing Concrete
Ring Lining

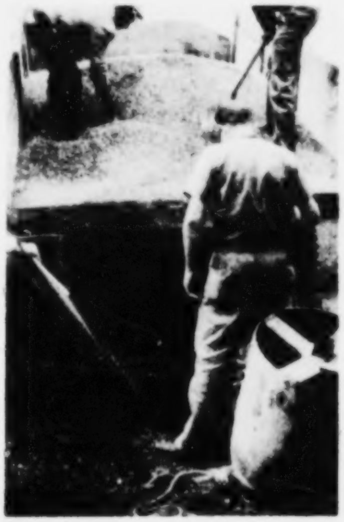


Figure 8

Gravel Backfill in
Annular Ring

Figure 9

Filling Pit for
Percolation Test

Access into the operating pit was maintained during the percolation testing, and the depth of ponded effluent was measured at several times during the day including one measurement early in the norming prior to anyone's arising. These readings provided data on the range in diurnal variation of effluent depth. Upon completing the percolation test, the effluent was diverted to the percolation test pit, and measurement of effluent recession was started for the operating pit. Measurements were made daily for the first few days and then less frequently for a period of a few weeks. This step completed the detailed study and the yard was returned to conditions which were satisfactory to the property owner.

SUMMARY OF RESULTS

The studies conducted encompass a wide range of control procedures, construction practices, and soil formations. However, sites were selected so as to maintain these factors uniform within each survey unit. Subdivision names or arbitrary soil designations were used to identify each unit. In some cases secondary classifications had to be made to separate different construction practices within a soil unit. In the following discussions twenty-two study units are identified in this manner.

Gross Performance.

Review of Records. Data obtained from records of health departments, local FHA offices, and septic tank installers were reviewed to obtain estimates of over-all seepage pit performance. General survey data indicated that this information was of doubtful value in judging performance. Complaints of failure found in the files were not indicative of the true failure rates because many failures were corrected without notifying control agencies.

Construction and Loading. Construction and loading data for the general surveys are presented in Table 2. Seepage pit construction practices vary considerably from county to county. For example, all seepage pits observed in San Diego County, California, were 3 feet in diameter whereas seepage pits observed in Maricopa County, Arizona, ranged from 2.1 to 5.1 feet in diameter. Median seepage pit depths ranged from 10 to 58 feet. Most of the pits were lined. Septic tank capacities ranged from a low of 500 gallons to a high of 1650 gallons.

Table 2

Construction and Loading Data

County	Subdivision or Soil Unit	No. of Obs.	System Age (Yrs.)		Water Use ($Ft^3/Yr.x\ 10^{-3}$)		Person Load (No.)		Septic Tank Capacity (Gals.)		Seepage Pit Data Diameter (Ft.)		Depth (Ft.)		Sidewall Area (Ft^2)	
			Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range	Median	Range
San Diego, Calif.	A Soil Fine	16	3.4	0.8-6.9	10.4	3.1-20.3	4.0	2.0-6.6	-	-	All 3.0		36	31-51	298	255-443
	A Soil Coarse	27	3.7	2.5-9.9	13.5	7.2-20.5	4.2	2.0-7.4	-	-	All 3.0		23	17-31	174	132-256
	B Soil	49	4.0	1.0-9.0	11.0	3.9-30.8	4.0	1.7-8.3	-	-	All 3.0		46	20-69	395	187-610
	C Soil	36	7.6	2.5-11.6	9.2	4.7-15.6	3.6	1.9-6.3	-	-	All 3.0		35	20-54	298	172-464
	D Soil	22	3.7	1.3-9.6	11.6	6.3-18.1	4.0	2.1-7.0	-	-	All 3.0		58	52-64	503	461-552
	E Soil	10	8.6	2.6-17.2	10.6	4.8-19.7	3.9	1.6-6.2	-	-	All 3.0		57	36-59	493	319-523
Maricopa, Ariz.	East Broadway Additions															
	Septic Tanks	37	3.8	0.9-11.0	10.6	3.8-26.1	3.0	1.7-8.8	550	500-810	3.7	2.4-5.1	10	7-14	79	43-163
	Cesspools	21	3.4	1.8-11.4	7.1	3.5-13.7	3.0	2.0-7.1	None		3.7	2.1-4.3	8	7-15	82	57-156
	Maryvale Parks Shallow Soil	35	4.2	3.8-6.0	9.1	5.4-15.4	4.0	1.7-6.0	550	550-750	4.0	2.7-4.5	16	14-18	151	87-186
	Squaw Peak Heights & McLellan Manor	44	5.1	3.0-6.5	9.2	4.6-26.2	3.4	1.3-6.0	500	500-1000	3.0	2.6-4.6	22	10-32	162	76-412
	Maryvale Parks Deep Soil	23	5.8	1.4-6.2	10.1	6.0-17.3	3.6	2.0-6.0	500	500-750	2.7	2.5-3.9	26	20-33	183	145-350
	Belden Courts, Campo Bello, & Griffith Park	98	5.4	0.2-6.6	9.2	4.3-19.2	3.3	1.7-7.0	500	500-750	2.6	2.1-3.7	29	11-38	219	98-418
Fresno, Calif.	Ferrosol Soil*	36	7.0	4.6-8.5	-	-	3.0	2.3-5.0	1000	810-1650	4.0	4.0-4.2	11	9-14	103	89-134
	Brown Alluvial Soil*	124	6.5	3.2-11.7	-	-	3.9	2.0-7.0	1000	810-1650	4.0	3.1-4.2	15	11-20	150	90-389
Sacramento, Calif.	Casa Bella Park & Orangevale*	27	3.6	1.6-5.7	-	-	4.0	1.8-6.6	1000	1000-1650	All 2.7		20	15-38	167	116-326
Santa Clara, Calif.	Loree Estates & El Quito Park*	87	6.9	5.0-8.8	8.7	6.1-16.1	4.0	2.0-5.8	All 810		All 4.2		16	10-27	156	103-256
Nueces, Texas	Ebory Acres															
	With Rock Filters	41	9.9	8.3-10.6	7.8	4.5-13.0	3.1	2.0-6.0	All 500		All 2.2		22	15-31	150	97-264
	Without Rock Filters	15	10.7	5.7-10.9	6.6	5.2-11.4	3.0	2.0-5.0	All 500		All 2.2		26	12-41	200	71-276
Los Angeles, Calif	Point Dume	62	1.6	0.3-10.0	-	-	3.0	1.0-8.0	750	750-1650	-	-	-	-	-	-
Jefferson, Ky.	Shively Area*	69	7.0	2.5-19.8	6.0	4.0-10.0	4.0	2.0-7.0	All 500		All 4.0		16	13-20	151	122-204

*The number of measurements of a particular factor varied from the tabulated number of observations; - data not obtained.

The shape of septic tanks was usually governed by the type of equipment used to excavate the seepage pits since this equipment was also used to make the septic tank excavation. A majority of counties where studies were conducted required a minimum of two compartments in septic tanks.

Data for household appliances which may affect system loading are summarized in Table 3. The percentage of homes with a food waste grinder, dishwasher, or water softener is highly variable among the different areas. Food waste grinders were installed by the builders in some subdivisions; therefore, virtually all homes in some survey units were equipped with this appliance.

The regeneration wastes from water softeners were seldom discharged to the septic tank system. The softeners were either regenerated off the premises or the wastes were discharged to the ground surface. A clothes washer was used in nearly all homes, but the relative proportion of manual sequence to automatic sequence units varied greatly among subdivisions.

Performance Table. Table 4 summarizes the over-all performance of systems for which complete information was obtained in the general surveys. A system's performance is classified as either failed or satisfactory from the reported history and an on-site inspection. The inspection was performed to determine that the failure was a true soil failure.

Locations indicated in Table 4 represent not only widely varying soil formations but varying construction practices, loading rates, and climatic conditions. Therefore, the performance data cannot be compared to rank the various soil formations. The information is presented as gross statistics to demonstrate observed levels of performance under actual conditions of construction and use.

Table 3

Household Appliances

County	Subdivision or Soil Unit	Percentage of Homes with Appliance					
		Food Waste Grinder	Dishwasher	Water Softener	Manual Washer	Automatic Washer	History of Both
San Diego, Calif.	A Soil (Fine)	50	0	44	12	82	6
	A Soil (Coarse)	82	4	41	4	74	22
	B Soil	31	2	53	14	63	23
	C Soil	6	0	44	36	31	31
	D Soil	73	0	44	18	59	18
	E Soil	10	0	60	10	10	80
Maricopa, Ariz.	East Broadway Additions						
	Septic Tanks	14	0	16	46	35	11
	Cesspools	5	0	5	86	5	0
	Maryvale Parks						
	Shallow Soil	3	3	9	11	55	29
	Squaw Peak Heights & McLellan Manor	30	23	50	7	70	7
	Maryvale Parks						
	Deep Soil	4	9	9	9	65	17
	Belden Courts, Campo Bello & Griffith Park	4	0	5	39	42	11
Fresno, Calif.	Ferrosol Soil	17	33	0	17	67	16
	Brown Alluvial Soil	5	10	0	5	62	28
Sacramento, Calif.	Campo Bello & Orangevale	7	0	0	22	60	18
Santa Clara, Calif	Loree Estates & El Quito Park	3	3	29	18	52	26
Nueces, Texas	Ebony Acres						
	With Rock Filters	5	2	0	30	58	12
	Without Rock Filters	0	0	0	14	50	15
Los Angeles, Calif.	Point Dume	74	11	21	18	74	-
Jefferson, Ky.	Shively Area	1	3	0	41	56	-

Table 4

Gross Performance

County	Subdivision or Soil Unit	System Age (Yrs.) Mean	System Age (Yrs.) Range	Person Load Mean	Mean Sidewall Area(Ft^2)	No. of Obs.	Performance No. Failed	Performance No. Satisfactory	Performance Percent Failed
San Diego, Calif	A Soil								
	Coarse	4.2	2.5-9.0	4.4	180	27	1	26	4
	Fine	3.4	0.8-6.9	4.2	316	16	0	16	0
	B Soil	4.9	1.0-9.0	4.2	391	49	2	47	4
	C Soil	7.6	2.5-11.6	3.6	295	36	4	32	11
	D Soil	4.8	1.3-7.4	4.1	500	22	1	21	4
	E Soil	8.9	2.6-17.2	3.8	475	10	0	10	0
Maricopa, Ariz.	East Broadway Additions								
	Septic Tanks	4.1	0.9-10.0	3.7	87	37	15	22	41
	Cesspools	3.1	0.7-10.7	3.7	92	21	9	12	43
	Maryvale Parks								
	Shallow Soil	4.1	1.8-6.0	4.0	150	35	2	33	6
	Squaw Peak Heights & McLelland Manor	4.8	2.3-6.5	3.4	170	44	13	31	30
	Maryvale Parks								
	Deep Soil	5.2	1.4-6.2	3.6	183	23	10	13	43
	Belden Courts, Campo Bello, & Griffith Park	4.5	0.2-6.6	3.3	224	98	21	77	21
Fresno, Calif.	Ferrosol Soil	7.0	2.0-11.0	4	106	36	13	23	36
	Brown Alluvial Soil	6.5	1.0-11.7	4	159	124	47	77	38
Sacramento, Calif.	Casa Bella Park & Orangevale	3.2	1.6-4.9	3.9	188	27	12	15	44
	Arden Glen	3.3	2.8-3.6	4.0	175	7	2	5	29
Santa Clara, Calif.	Loree Estates & El Quito Park	7.0	2.5-8.8	3.9	153	87	21	66	24
	Lovell Avenue	8.8	6.7-9.3	3.4	130	21	2	19	10
Nueces, Texas	Ebony Acres								
	With Rock Filters	4.2	0.8-9.5	3.6	163	41	41	0	100
	Without Rock Filters	3.7	1.0-10.6	3.0	206	15	14	1	93
Los Angeles, Calif.	Point Dume	2.4	0.3-10.0	3.2	-	62	7	55	11
Jefferson, Kentucky	Shively Area	7.4	2.5-19.8	3.8	156	69	23	46	33
All Soils Combined		5.7		3.7	196	907	260	647	29

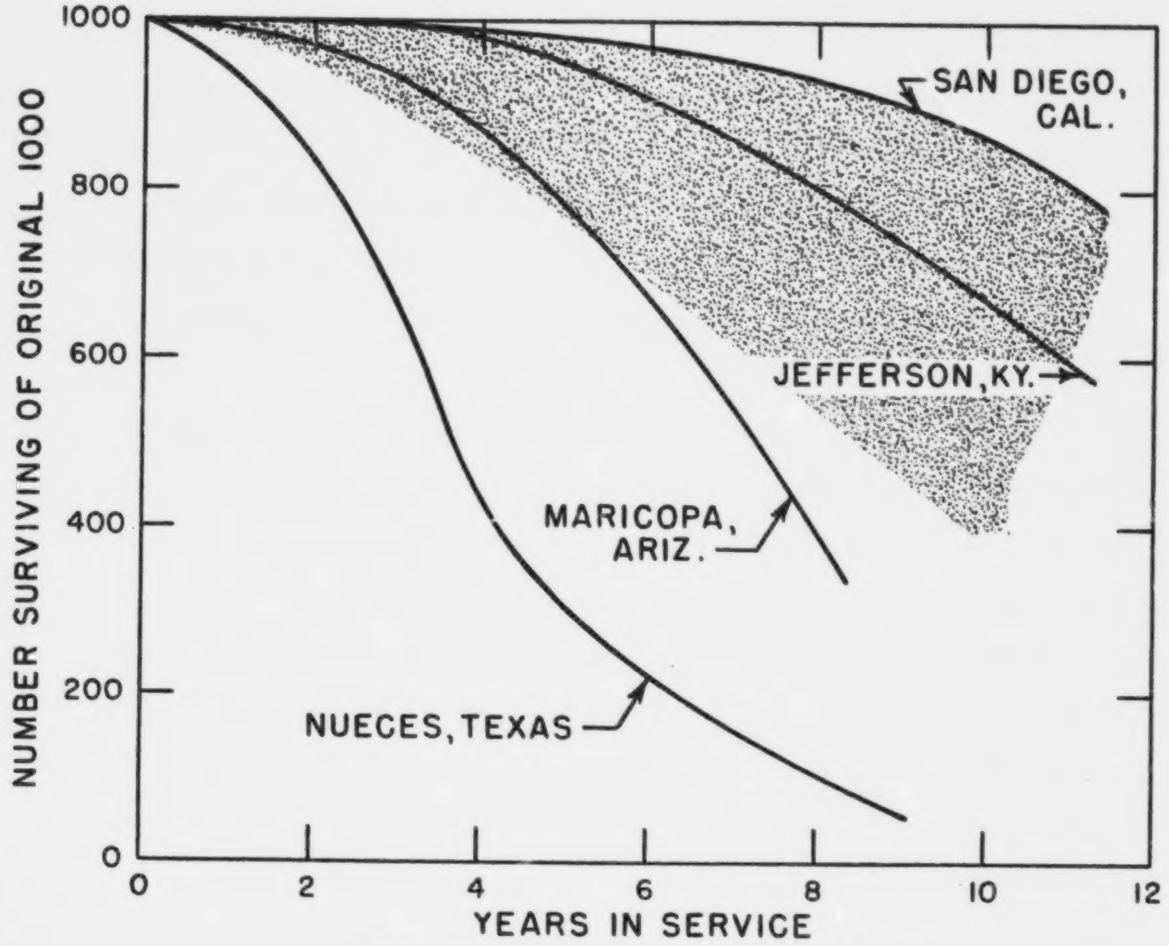
Of the 907 systems observed having a median age of 5.7 years, 260, or 29 percent, had failed; excluding Nueces County where construction practice was judged to be a primary cause of failure, 205 out of 851 systems, or 24 percent, had failed. While these failure rates may seem high, they appear reasonable for the relatively small amounts of absorption area provided for the loads imposed. In San Diego County, California, where the median absorption area was 346 square feet, only 5 percent of the 160 systems had failed.

Survival Curves. Performance data presented as mortality-type survival curves are shown in Figure 26 for four of the study areas. Curves of this type relate failure age to the total number of systems within a given time interval. The curve for Nueces County, Texas, demonstrates a high incidence of failure in the first few years of operation; this was probably due to poor construction practice. Some of the curves include data from several soils and all curves are affected by variations in loading and construction. Therefore, they do not afford a direct comparison of the individual areas. The curves do indicate that in suitable soils and with proper construction the seepage pit may be a feasible device for disposing of septic tank effluent.

Soil Area Used.

The previous sections provide qualitative estimates of seepage pit performance. In order to obtain a quantitative evaluation of performance, the amount of soil area used as related to load and time must be investigated.

When a new seepage pit is put into operation sufficient soil area is wetted to establish equilibrium between the daily volume of septic tank effluent applied and the transmission rate into the soil. As time goes on,



GROSS SURVIVAL CURVES
SEEPAGE PITS
FIGURE 26

soil clogging reduces the average transmission rate, and additional increments of soil area are wetted to maintain a quasi equilibrium between the daily input and average transmission rate. In this manner, effluent rises gradually in the pit and eventually floods all of the available absorption area.

The rate at which new soil absorption area is wetted is a function of the quantity and quality of the liquid applied, the initial transmission rate of the soil, and the rate at which soil clogging reduces the initial transmission rate. Soil clogging ultimately reduces the transmission rate to a small value very close to zero. With reasonable accuracy, it can be assumed that the transmission rate follows a decreasing exponential curve with time in service.

A mathematical model developed in a previous report(1) expresses the above relationships as follows:

$$(1) \quad A = \frac{Q}{kL} + \frac{Q}{L}t$$

where:

A is the total amount of absorption ares, in square feet, used during time, t

t is the time in service in years,

k is the rate reaction constant of clogging per year,

L is the cubic feet of effluent that one square foot of soil will ultimately absorb, and

Q is a loading factor which includes several subfactors that relate to the quantity and characteristics of effluent applied to the soil.

Some of these factors are the volume of liquid applied, the amount of treatment given to the sewage both in the septic tank and in the soil absorption system before liquid comes into contact with the soil, the number of persons using the system, and the use of modern household appliances.

Using area, load, and age data collected in the general surveys (shown in the appendix) values for k and L were determined for each soil or subdivision unit studied. Substituting these values in equation (1) and assuming a water use of 50 gpcd and a home occupancy of four persons (equivalent to a three-bedroom home), an area equation was developed for 15 soil units studied. In all cases the first term (referring to equation (1)) was insignificant and the equations for all soils reduced to one parameter models. The equations are shown in Table 5.

Economic Approach to Design.

The equations shown in Table 5 give a reasonable value for the design area required in each of 15 soils to provide for any given renewal period. The equations imply, and experience had indicated, that ultimately virtually all soil absorption systems must fail and be replaced if continuing utility is to be expected. The total cost of such systems can be conveniently divided into two components, the cost of the initial installation and the costs of subsequent replacements. Within any convenient time horizon, there is one renewal period that will minimize the total cost of initial installation and subsequent replacements. For example, if an unnecessarily large initial capacity is provided, the system will be uneconomic in that it involves investment for absorption capacity that will not be used for many years. On the other hand, a short renewal period with overfrequent replacements will make the cost excessive.

Table 5

Area Equations

Seepage Pits

County	Subdivision or Soil Unit	Mathematical Model Equation*
San Diego, Calif.	A Soil (Coarse	$A = 13.5t$
	A Soil (Fine)	$A = 31.8t$
	B Soil	$A = 41.8t$
	C Soil	$A = 25.8t$
	D Soil	$A = 53.7t$
	E Soil	$A = 27.3t$
Maricopa, Ariz.	East Broadway Additions	$A = 18.2t$
	Maryvale Parks (Shallow Soil)	$A = 22.4t$
	Squaw Peak Hgts. and McLellan Manor	$A = 30.9t$
	Maryvale Parks (Deep Soil)	$A = 37.4t$
	Belden Courts, Campo Bello, and Griffith Park	$A = 50.4t$
Fresno, Calif.	Ferrosol Soil	$A = 22.4t$
	Brown Alluvial Soil	$A = 28.2t$
Sacramento, Calif.	Casa Bella Park and Orangevale	$A = 53.6t$
Santa Clara, Calif.	Loree Estates and El Quito Park	$A = 22.8t$

---

*A = usable sidewall area in square feet per home;

t = time in service in years.

In order to compare costs on a common basis future replacement costs can be discounted to the present and the total costs expressed in terms of present value. Methods for doing this and for determining the most economic renewal period are presented elsewhere (1)(2)(3).

From interviews with builders and contractors in the 8 study areas it was determined that the cost of a new seepage pit could be estimated from a fixed charge of $78.00 plus $48.00 per 100 square feet of absorption area provided. The fixed cost of $78.00 includes an estimate for costs of administration and enforcement. The cost of replacing a seepage pit was estimated to be about 1.2 times as much as the cost of a new pit.

Employing the economic analyses referred to with an economic time horizon of 30 years, an interest rate of 5 percent and the cost data above optimum renewal periods and the corresponding design areas were determined for each of the 15 soils. These values are shown in Table 6.

In using economic analyses for determining optimum design, two constraints must be taken into consideration. A minimum design period must be met that is acceptable to health departments and other control agencies. With this constraint an optimum renewal period minimizing over-all costs would be used in actual design only if it exceeded the minimum permissible value. While it is not the purpose of this report to set such a value, a minimum return period of 10 years would seem reasonable. The second constraint arises from a practical consideration that the theoretical optimum renewal period may result in an initial cost that exceeds the financial resources of the builder.

Table 6

Economic Analysis Results

County	Subdivision or Soil Unit	Optimum Renewal Period (Years)	Optimum Design Area* (Ft^2/Bedroom)
San Diego, Calif.	A Soil (Fine)	12	127
	A Soil (Coarse)	18	81
	B Soil	11	153
	C Soil	13	112
	D Soil	10	179
	E Soil	13	116
Maricopa, Ariz.	East Broadway Additions	16	97
	Maryvale Parks (Shallow Soil)	14	105
	Squaw Peak Heights and McLellan Manor	12	124
	Maryvale Parks (Deep Soil)	11	137
	Belden Courts, Campo Bello, and Griffith Park	10	168
Fresno, Calif.	Ferrosol Soil	14	105
	Brown Alluvial Soil	13	122
Sacramento, Calif.	Casa Bella Park & Orangevale	10	179
Santa Clara, Calif.	Loree Estates & El Quito Park	14	106

* Useable sidewall area.

Soil Evaluations.

A variety of soil investigations were made at several sites within each soil or subdivision unit. A description of each discernible stratum at each site was logged as excavation of a test pit proceeded. Bulk and core samples were collected for density, texture, moisture, and porosity determinations. Soil penetrometer tests were made on each stratum in place. On completion of logging and sampling a full scale percolation test was conducted at each site.

Representative data were analyzed to relate mass density, texture, and penetrometer values and combinations of the three to system performance. Some correlation was obtained but the relationships were too weak to be of practical use. Chalk tests(4) for estimating porosity also proved of little practical use.

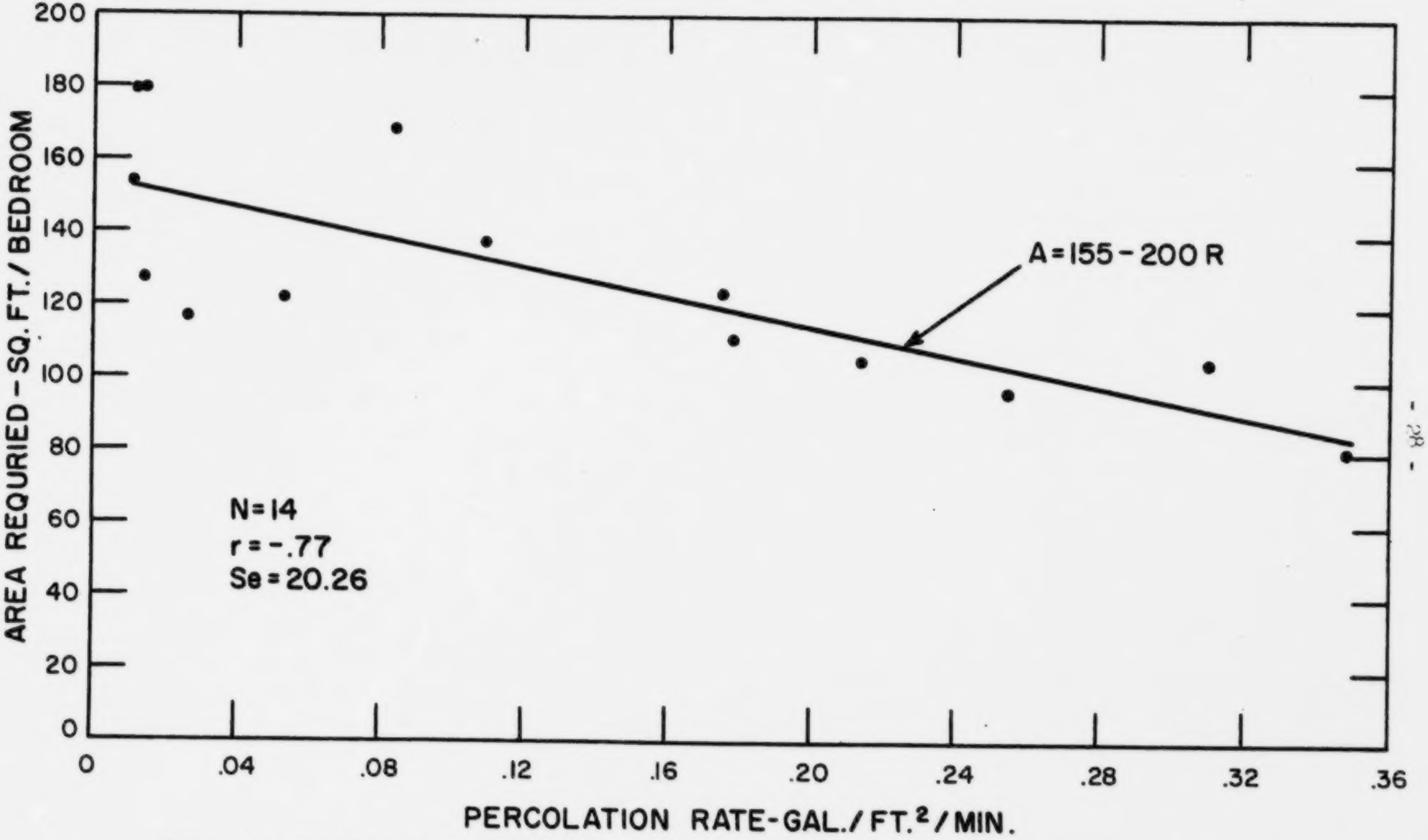
Percolation test results and visual soil ratings developed from profile descriptions showed the best relationships to system performance. A summary of this data along with optimum design areas for 14 soils is shown in Table 7.

Percolation Test. The percolation test procedure employed in these studies was patterned after a combination of a method developed jointly by the Federal Housing Administration and the Sacramento Department of Public Health, and the method used for shallow soils outlined in the Manual of Septic Tank Practice(5).

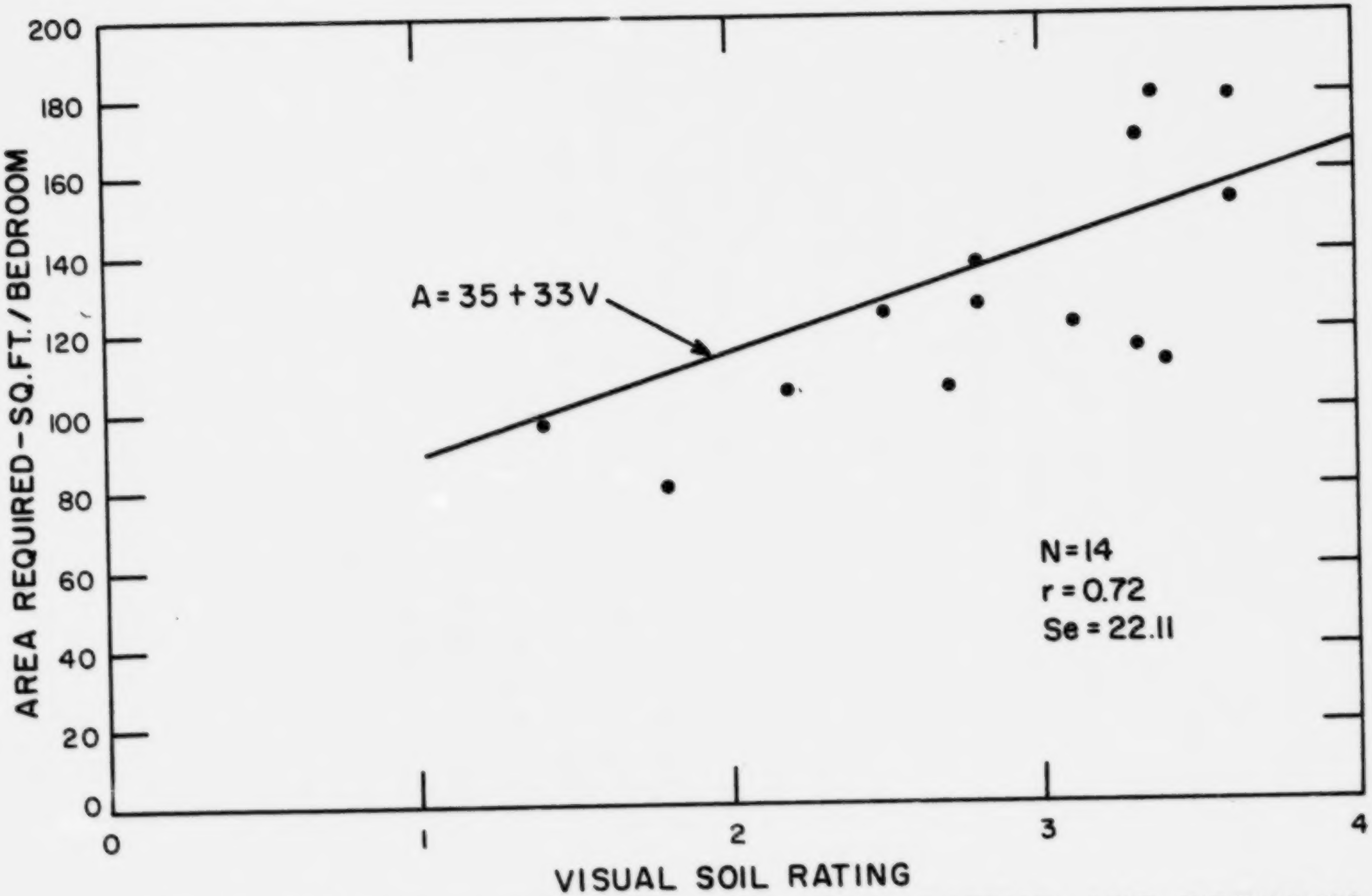
Table 7

Soils Test Results

County	Subdivision or Soil Unit	Percolation Rates (Gal./ft²/min.) No. of Obs.	Mean	Std. Dev.	Range	Visual Soil Rating Mean	Std. Dev.	Range	Optimum Design Area (Ft²/Bedroom)
San Diego, Calif.	A Soil								
	Fine	3	.014	-	.003-.033	2.8	-	2.7-3.0	127
	Coarse	5	.348	.632	.063-1.380	1.8	0.3	1.5-2.2	81
	B Soil	6	.011	.012	.001-.033	3.6	0.2	3.1-3.7	153
	C Soil	6	.178	.332	.015-.856	3.4	0.1	2.8-3.5	112
	D Soil	2	.012	-	.005-.019	3.6	-	3.5-3.8	179
	E Soil	2	.026	-	.008-.044	3.3	-	- -	116
Maricopa, Arizona	East Broadway Additions	3	.254	-	.050-.494	1.4	-	1.0-1.9	97
	Maryvale Parks, Shallow	2	.310	-	.053-.567	2.2	-	2.2-2.2	105
	Squaw Peak Heights & McLellan Manor	5	.175	.098	.076-.310	2.5	0.2	2.3-2.7	124
	Maryvale Parks, Deep	5	.109	.068	.015-.183	2.8	0.3	2.6-3.2	137
	Belden Court, Campo Bello & Griffith Park	6	.084	.030	035-.124	3.3	0.2	2.9-3.8	168
Fresno, Calif.	Ferrosol Soil	11	.213	.193	.038-.598	2.7	0.4	2.2-3.4	105
	Brown Alluvial Soil	21	.054	.060	.003-.217	3.1	0.5	1.8-3.7	122
Sacramento, Calif.	Casa Bella Park & Orangevale	19	.013	.012	.001-.042	3.2	0.5	2.3-3.8	179



RELATIONSHIP BETWEEN PERCOLATION RATES AND OPTIMUM DESIGN AREAS FOR SEEPAGE PITS
FIGURE 27



RELATIONSHIP BETWEEN VISUAL SOIL RATING AND OPTIMUM DESIGN AREAS FOR SEEPAGE PITS
FIGURE 28

The tests were conducted in full-sized seepage pits of the same dimensions as the pit or pits being evaluated. The procedure is as follows:

1. Excavate a conventional seepage pit of the same diameter and depth as the operating pit within 20 feet and not closer than 10 feet to that pit.
2. Install a lining of the type used in the area being studied and place one foot of gravel in the bottom of the excavation.
3. Fill with clear water, through the use of a tank truck or other suitable means, to the elevation of the ground surface.
4. Allow the water level to recede to one-half the depth of the pit or until the depth of the water is 5 feet, whichever is least. Refill and allow to drain overnight(5). On the second day refill again and time the recession of the water level to the mid-depth or the 5-foot depth, whichever is least.
5. From a plot of the rate of recession versus depth of water in the pit, the percolation rate in units of gallons per minute per square foot of wetted area is calculated over any depth of the pit desired.
6. Three percolation tests should be conducted in each subdivision.

The percolation rates shown in Table 7 were calculated over a depth of the pit equal to the depth of ponded effluent in the operating seepage pit at the test site.

In the evaluation of a new area the percolation rate would be calculated over the full depth of the useable area of the pit.

Visual Rating. Each soil stratum encountered during excavation of a pit was rated on a scale of one to four. The rating was based primarily on visual evaluations of texture, structure, density, and degree of cementation or compaction. A description of the four visual rating classes is as follows:

1. Clean gravel or sand, very loose.
2. Clean gravel or sand, loose to firm;
   Sandy loam, friable.
3. Clean gravel or sand, firm to dense;
   Sandy loam, firm to dense;
   Loam to sandy clay, friable.
4. Silty clay or heavier, dense to very dense.

Individual stratum ratings were weighted for thickness of stratum in determining the average rating for the entire pit or over any depth of the pit desired.

The relationship between percolation rate and optimum area and between visual rating and optimum area are shown graphically in Figures 27 and 28. These figures provide a reasonable means for estimating design size for seepage pits in a variety of soils.

GENERAL OBSERVATIONS

Construction Practices.

Construction practices vary from locality to locality depending upon the available construction material and equipment, local soil and topography, personal preferences, and local experience.

The general survey and detailed study procedures provided an opportunity to observe many construction practices. These observations indicate that proper construction is of major importance in obtaining satisfactory performance of septic tank-seepage pit systems.

Excavation. Many methods of digging seepage pits are in common use. These range from time-honored hand digging to the use of specially designed augering equipment. Hand digging is resorted to only in isolated instances where topography prevents the use of conventional or special excavation equipment, or where the small number of systems being installed makes it uneconomical to use mechanical equipment. In the event of hand digging, caving protection and safety techniques such as slip linings or sheet or ring spiling must be employed.

Types of conventional excavation equipment commonly used are backhoes, clamshells, and orange peels. Backhoes are used to dig shallow pits with a relatively large cross-sectional area. Such pits must usually be lined or filled with stone. Clamshells and orange peels are often used to dig inside of slip linings in very loose formations.

By far the most extensively used seepage pit excavation equipment in the west is a modified earth auger of the type used for foundation explorations. Figures 10 and 11 illustrate two types of this equipment. The machine illustrated in Figure 10 brings the excavated soil to the surface on a flat plate. Spinning the plate throws the soil away from the excavation. The machine shown in Figure 11 traps the excavated material in the bucket as it is loosened. The bucket is lifted clear of the excavation and the power ring, and the excavated soil is dumped away from the excavation by tripping the hinged bottom.

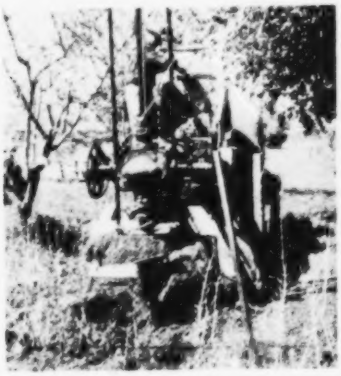


Figure 10

Spinner Plate Seepage Pit Auger

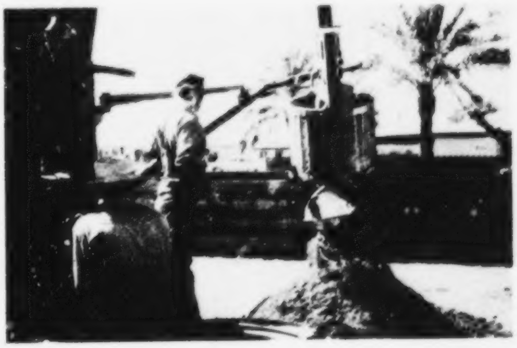


Figure 11

Bucket Seepage Pit Auger

The spinner plate machine is limited to digging pits to a maximum depth of about 20 feet, while the bucket-type machines are capable of digging pits over 100 feet deep. The greater depth is obtained by adding extensions to the vertical shaft as excavation progresses. Many of the bucket machines have a telescoping shaft which makes it possible to drill up to about 45 feet deep without adding extensions.

The spinner plate machine is also limited to digging a pit of the same diameter as the cutting head, commonly two to five feet. A bucket machine can excavate a pit of the same diameter as the bucket, from 18 inches to 4 feet, or by the use of adjustable cutting tools installed on the edge of the bucket, it can also ream a hole up to about 6½ feet in diameter. The stub of the pilot hole remaining in the bottom of the pit is usually backfilled with the last excavated earth or with clean gravel to form a firm foundation for the lining.

Reaming tools are also used to enlarge the top of a pit to provide a foundation for the pit dome as shown in Figure 12.

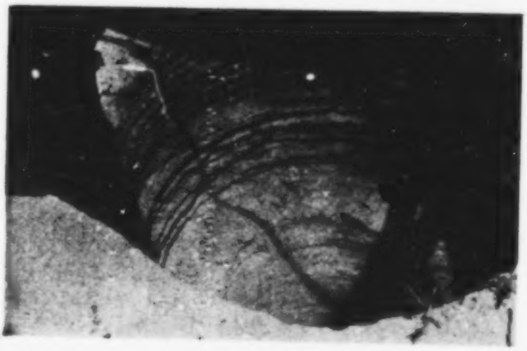


Figure 12
Foundation Ledge for
Pit Dome

Lining Practices. In a few local situations, seepage pits are used without lining or support for the pit sidewalls. This type of construction occurs primarily in areas where relatively thick strata of consolidated or cemented soil materials are penetrated before encountering a suitable porous stratum. Many such pits have been observed that are apparently standing satisfactorily while others have caved badly. Since it is difficult to forecast whether or not a soil will stand without support, most pits were lined or rock filled to provide structural stability.

Two types of rock filled seepage pit construction were encountered. In one type, the pit is filled to within a few feet of the ground surface with stone four to six inches in diameter. A concrete slab cover is placed directly on the stone. The effluent inlet may enter through the cover or through the pit sidewall. In the second type, the pit is filled with gravel to within 10 feet of the ground surface and a porous lining is used over the remaining depth.

Most of the pits observed have been lined over their full depth. Standard brick, building block, radial concrete block, redwood lumber, and precast concrete rings are lining materials most commonly used.

Standard brick linings are constructed by laying unmortared tiers of bricks against the raw wall of the seepage pit as shown in Figure 13. The brick may be abutted tightly as shown or a space of one-quarter to one-half

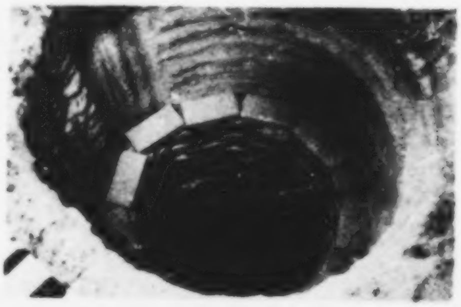


Figure 13
Brick Lining Under Construction

inch left between adjacent brick. Common practice is to lay the brick flat, but some contractors lay the brick on edge which is poor practice.

Several types of radial concrete block are used for seepage pit linings. The dimensions and design of these block vary according to local preference, but they are generally designed to fit tightly into a specific diameter pit. Three types of block are shown in Figures 14. Those in Figure 14-a are the most common type, with ends butting flat against each other. It is assumed that the unmortared joints are sufficiently large to allow the passage of effluent. The blocks in Figure 14-b are provided with interlocking end joints, and those in Figure 14-c have "weep" holes to insure passage of effluent. Usually, radial block and brick linings are installed by hand.

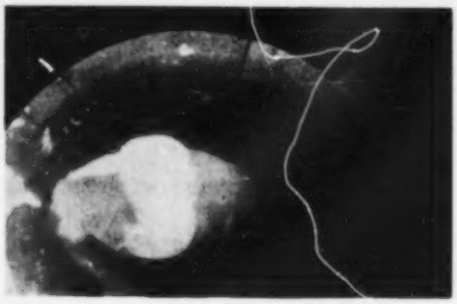


Figure 14-a

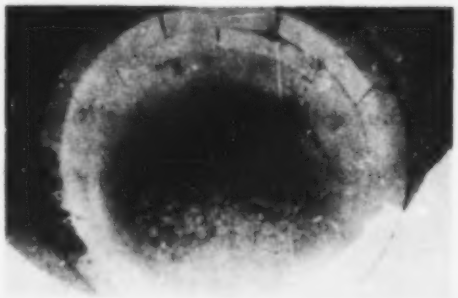


Figure 14-b

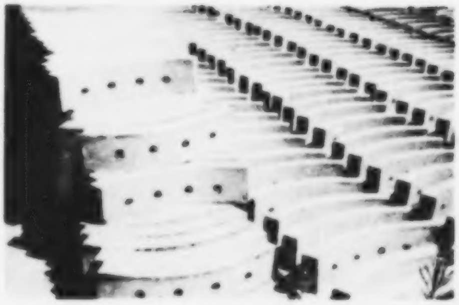


Figure 14-c

Concrete Radial Block for Seepage Pit Linings

In deeper pits and in situations where it is dangerous for a man to work in the pit, bricking machines have been used as an alternate method. One type of bricking machine has a circular steel plate with a series of retractable lugs around its circumference. The plate is connected by cable to the power hoist. The first tier of block is placed on the bricking plate lugs, and succeeding tiers are added as the plate is lowered into the pit. When a lining height of five or six feet is reached it is lowered to the bottom of the pit, the lugs are retracted and the plate is returned to the surface for reloading. The finished lining with a bricking machine generally does not fit the excavation quite as tightly as when it is built by hand.

Another type of lining observed is made from the precast concrete rings shown in Figures 15. The rings which may or may not have "weep" holes are made in various lengths. They are particularly popular in areas with caving sands which require a caisson method of excavating. A hole slightly larger than the rings is excavated, generally with a clamshell, orange peel,

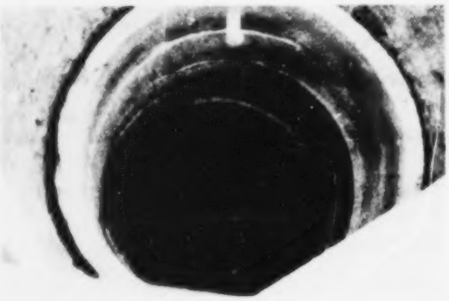


Figure 15-a

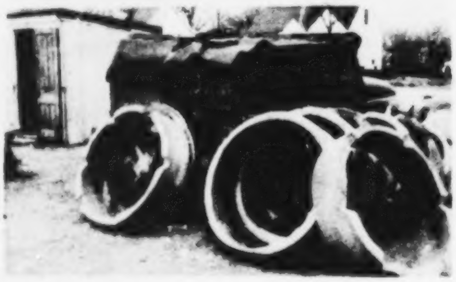


Figure 15-b
Precast Concrete Ring Lining

or by hand, to the level of the sand. The rings are then placed in the hole and excavation continued by digging out from under the rings and allowing them to slip down. Rings are added until the desired depth of the pit is reached.

A type of lining used on the west coast consists of redwood lumber boards nailed to supporting ribs to form an open-ended cylinder or box. Figures 16 show an octagonal-shaped liner being fabricated and a box-shaped liner in place, respectively. The lining sections are made up in convenient lengths which are stacked on top of each other to form a continuous lining in the pit. The annular space between the lining and the pit wall is generally filled with gravel as seen in Figure 16-b.

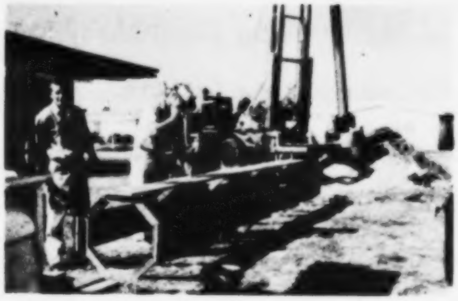


Figure 16-a

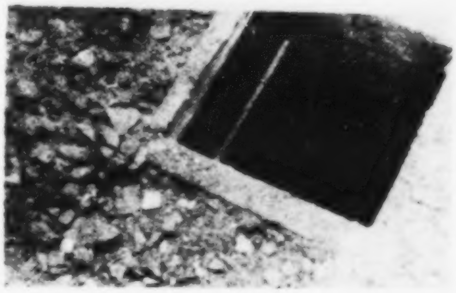


Figure 16-b
Redwood Lumber Lining

Domes and Lids. There are two types of covers, brick domes or flat concrete lids, which are generally used for seepage pits. Brick domes (Figures 17) are commonly constructed by laying the brick dry and covering the completed dome with mortar. The top of the lining or an earth ledge which extends out beyond the periphery of the excavation is used as a base for the dome. An inspection opening, as in Figures 17, fitted with a removable cover is often left in the peak of the dome.

Figure 17-a Figure 17-b

Seepage Pit Dome Cover

The inlet is usually brought into the side of the pit just below the dome as was seen in Figure 3. Poured-in-place concrete lids (Figure 18) are commonly used with the board-lined pits. They are generally extended 6 to 12 inches beyond the edge of the excavation.

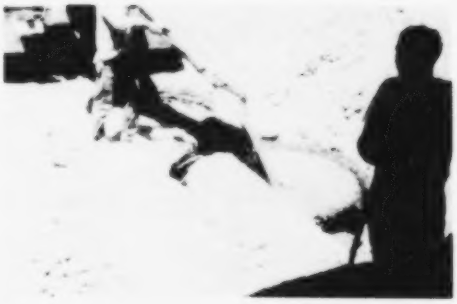


Figure 18

Concrete Slab Cover

Connecting Lines. The connecting lines between the septic tank and the seepage pit are an important and integral part of a system. Water-tight lines, four inches in diameter, were used in all study areas. Vitrified clay, concrete, asbestos cement, and bituminized fiber are usually accepted as suitable materials. Trench excavations are either made by hand or with the same equipment used for the pit. Trenches are usually too short to justify use of conventional trenching machines. A common practice is to drill several trench-depth holes along the line of the trench with a bucket-type auger. The soil between the holes is then caved in to form a continuous trench. While a convenient excavation technique, the method does not provide for a well-bedded connection line.

When a dome cover is used the connecting line usually enters the pit just below the dome. It may or may not have an elbow to divert the flow downward. With slab-covered pits the inlet may be brought in by means of a tee through the top slab in the center of the pit or through the sidewall just beneath the slab.

General practice at new installations is to connect multiple pits in parallel through the use of a distribution box. Most repair pits are connected in series with the old pit. These connections are generally made with straight sewer outlets and inlets. A few installers preferred a tee or ell outlet connection.

Repair Practices. The most common repair practice to correct a pit failure is to add one or more pits to the system. It is such a common practice that in many localities the homeowners deal directly with installers without consulting control authorities.

Pumping, blasting, acid treatment, and use of chemical and biological additives are frequently resorted to in attempting to correct seepage pit failures. Pumping is at best a temporary and expensive corrective measure. In one area homeowners had provided themselves with permanent pumping equipment so that the pit could be pumped every few weeks. Meager evidence indicates that blasting and acid treatment also provide only temporary relief. Blasting has been observed to cause structural damage resulting in a collapse of the seepage pit. Acid treatment usually consists of pumping out as much of the pit contents as possible and then adding from 5 to 25 gallons of commercial sulfuric acid. No evidence was found which would indicate that biological additives have had corrective value.

Construction and Sources of Malfunction.

Construction plays an important part in the success or failure of a seepage pit system. Faulty practice at any stage in construction may doom an otherwise satisfactory system to a premature failure.

Soil conditions usable for seepage pit systems at any given site have been fixed by nature. There is no practical way, as far as is known at present, to improve the natural capacity of soil materials to absorb effluent. However, a number of construction practices have been observed that can damage or literally destroy that capacity.

Practically all of the excavating methods encountered cause some soil damage, much of which can be avoided. The primary cause of damage is smearing or compacting of the excavated surface. The damage increases as the soil moisture content increases and as the textural size decreases. The detrimental effect of wet soils may be minimized by avoiding construction during wet periods.

Smearing damage was most frequently observed in unreamed pits. The bucket in Figure 19-a is an example of one of the common causes of smearing damage. This bucket has worn to the point where it has become slightly conical shaped, the bottom diameter being smaller than the upper diameter. In use, the upper portion of the bucket will rub tightly against and smear the sidewalls as the pit is deepened. The type and position of the cutting blade are also conducive to soil damage when the cutting blade has become dull. The knife-type of blade has a slicing, cutting action that tends to leave a smeared and compacted soil surface. Contrast this bucket with the one in Figure 19-b. Note protective hard

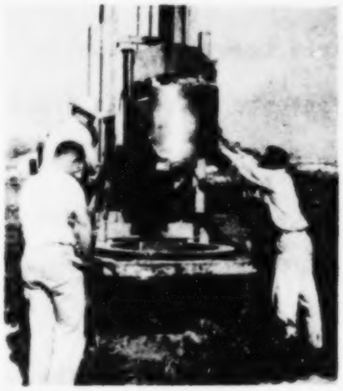


Figure 19-a

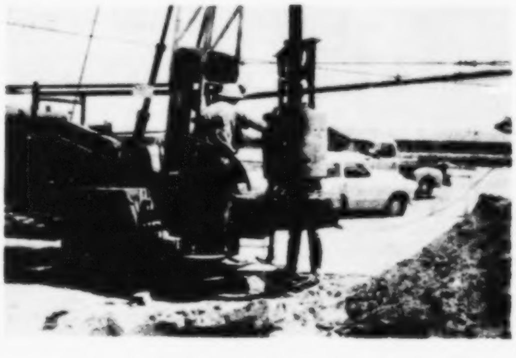


Figure 19-b

Type of Bucket Which May
Influence Soil Damage

surface ribbing and the truer cylindrical shape; also note the sharp cutting point extending out on the lower left edge of the bucket. This tool provides a tearing, cutting action that is more likely to leave a natural undamaged soil surface.

In Figure 20-a the soil surface was cut with a blade-type bucket; note the smeared surface at the bottom of the picture.

The soil surface shown in Figure 20-b was cut with a sharp, pointed tool. A much less damaged surface is apparent.

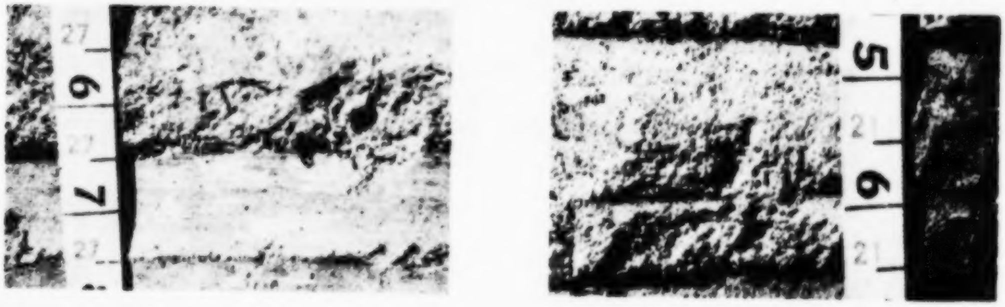


Figure 20-a Figure 20-b

Damaged and Undamaged Soil Surfaces

Sidewall smearing may also be caused by excessive wobbling of the bucket in the hole. Sharp cutting teeth minimize such wobble. It has also been observed that a hole may be drilled off plumb if the rig position is allowed to move after a hole is started. Rubbing of the bucket along one wall of such a pit as the bucket is withdrawn and inserted may completely seal the wall. With reasonable care on the operator's part during drilling and the use of well-kept equipment, a vertical excavation can be maintained and a great amount of smearing damage avoided.

Probably the best excavation technique observed as far as preserving the natural soil properties is the pilot hole-reaming method. Only a relatively small cutting edge is brought into contact with the soil so that a tearing action is more likely to result. The finished hole is 3 to 12 inches larger than the pilot hole, thus there is less chance of the bucket rubbing and smearing the finished sidewalls.

With the number of lining methods encountered, it is natural that a wide variety of malpractices would be observed. One of the most flagrant of these malpractices occurs during the laying of brick or block linings. Such linings seldom fit tightly against the pit wall so that an annular space of one to two inches is left between the pit wall and the lining. Many times a pit is not uniformly shaped (Figure 21) and large cavities exist behind the lining. In laying up linings in a pit such as this, workmen usually fill the spaces behind the brick with soil that has been excavated from the pit. Often the soil used for such fill is fine textured and relatively impermeable. Unfortunately, caving is more likely to

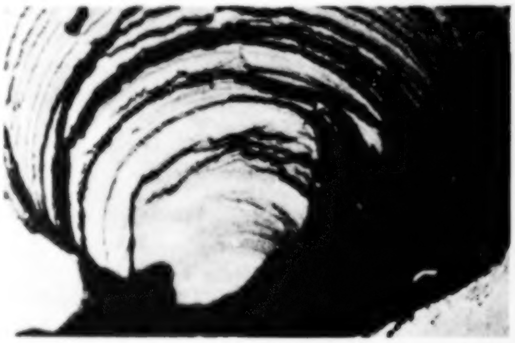


Figure 21
Pit Excavation in Caving Soil

occur in the more permeable strata, and consequently the possibility of damage is accentuated. Backfill behind the lining should always be clean coarse gravel.

With prefabricated lumber linings, the most recent practice is to fill the annular space between the lining and pit wall with gravel. However a large number of linings in old systems were observed that did not have gravel fill. In the opinion of the local health departments, gravel fill is necessary to insure the structural stability of the lining. The gravel fill at those sites observed was seldom found to extend to the top of the casing which may have been due to settlement or incomplete original fill.

Observation of rock-filled and gravel-filled pits during construction indicates they would afford a maximum of structural stability to a pit; however, this does not insure satisfactory performance. Successful operation of a rock-filled pit is dependent upon the effluent finding a passage through the rock fill to the permeable soil surface. Figure 22 shows a seepage pit where failure was caused by the formation of a sludge mat on the surface of the gravel. The size of gravel fill in this pit ranged up to 2 inches, but 25 percent of a sample taken

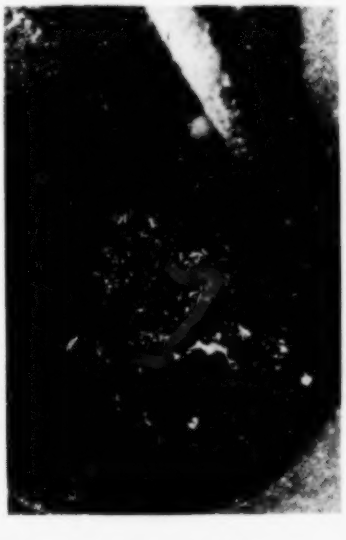


Figure 22

Sludge Mat in Gravel Filled Pit

passed a one-half inch screen. The fine material tends to fill the interstices between the large gravel and results in a rapid clogging.

Faulty construction practices were observed in the methods of providing a building base or foundation for brick and block linings. The common recommended procedure of placing a foot or two of clean sand or gravel in the bottom of the pit to form a firm foundation for the lining is seldom followed. In reamed holes, linings are often built on the unstable ledge where reaming of the pilot hole terminates. In other cases, the pilot hole is backfilled with material excavated from the pit, and the lining is started without any attempt to compact the fill material. Lining settlement of several inches which was undoubtedly a result of poor foundation conditions has been observed in old pits. Such settlement may lead to a variety of failures, such as breaking and separation of inlet lines, structural failure of linings and pit covers, and even complete pit cave-ins. Standard use of a two-foot fill of clean gravel in the bottom of the pit would provide a stable foundation for the lining.

Faulty foundation practices were also observed in the construction of pit covers. Generally, both the dome-type and flat-lid-type covers were built on undisturbed earth extending at least a foot beyond the periphery of the pit proper. This provides a structurally stable cover completely separate from the pit lining. However, in some areas where brick lining was predominant, the dome was merely a continuation of the lining. In such cases settlement or failure of the lining endangers the dome.

Materials used and construction practices followed in the installation of connecting lines have considerable influence on seepage pit dependability. Vitrified clay, concrete, asbestos cement, and bituminized fiber pipe were observed during the studies. In some localities concrete tile connecting lines (Figure 23) were in varying states of decomposition. However, in other cases concrete tile was used with apparent success. While it could not be demonstrated that the original quality of the concrete tile was responsible for the deterioration, this is strongly suspected. Regardless of the cause, there is need for quality control on all materials used in seepage pit systems.

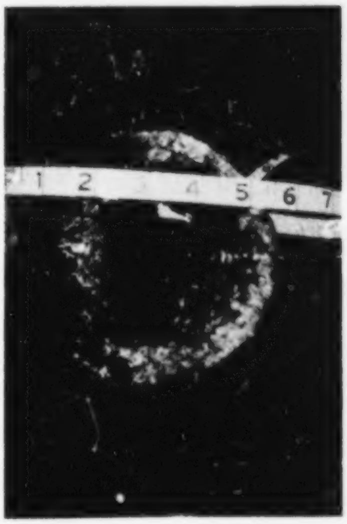


Figure 23

Concrete Connecting Line

Trench excavating and the bedding of connecting lines were observed to be haphazard operations and probably responsible for a number of failures. Figure 24-a shows a common method of excavating for connecting lines where auger equipment is used. Two shallow pits were augered between the distribution box (foreground) and the seepage pit dome just visible in the far pit. Holes were tunneled through the partitions between the first and second, and second and third, and the partition between the third and fourth was caved in. In a run of about 10 feet, the connecting line installed later was supported only at the outlet from the distribution box and on the third partition wall. Even where a full trench is dug as in Figure 24-b, often a continuous firm bedding or support for the connecting line is not provided. Some installations were observed where the pipe grades were carefully set and adjusted by propping the pipe on small stones or earth mounds at each joint. Under this circumstance the pipe is almost certain to be misaligned after backfilling and there is a good chance of breaks in the line or leaky joints. A number of systems were observed where breaks in the

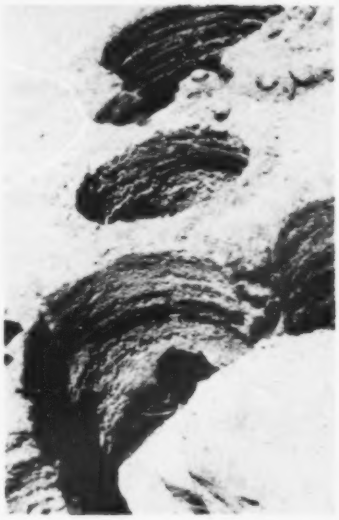


Figure 24-a

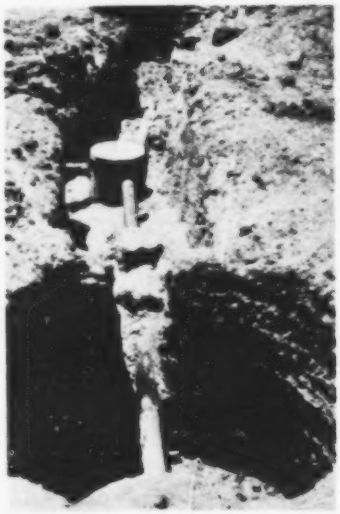


Figure 24-b
Bad Practice in Construction of Connecting Lines

line had occurred and effluent had flowed along the bottom of the trench to the pit. The pit sidewalls were eroded, the covers were undermined and the pit had caved in.

A final item of dubious construction practice was observed in backfilling procedures. After a system has been completed and is awaiting inspection, or even after it is inspected and approved, it may remain open for several days before being backfilled. During this time the open excavations make convenient trash pits for disposal of broken masonry, scrap lumber, and other waste material as shown in Figures 25. When the earth backfill is finally made, more often than not, no attention is paid to its compaction. Depressions then develop and funnel a large part of the yard surface drainage into the permeable backfill and thus into the pit. In one area where flooding irrigation was practiced, it was a common homeowner complaint that plumbing drainage was sluggish on irrigation days. Immediate backfilling of excavations and care in compaction would eliminate a large measure of this type of trouble.

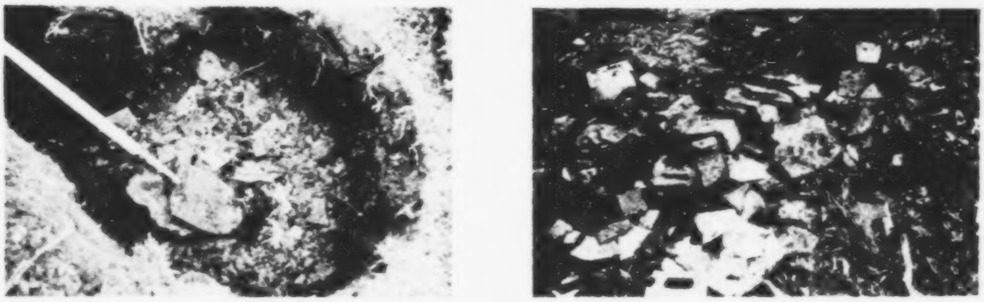


Figure 25-a Figure 25-b

Trash Fill Over a Seepage Pit

DESIRABLE CONSTRUCTION AND CONTROL PRACTICES

Preferred construction practices may vary from area to area depending on local soil and geology, equipment and construction materials available, and other local circumstances. The following suggestions, based on the observations made in the field, are offered as major points to be considered to obtain good seepage pit construction.

Excavating.

As previously discussed, soil is susceptible to damage during excavation. Digging in wet soils should be avoided as much as possible. Cutting teeth on mechanical equipment should be kept sharp. Bucket augered pits should be reamed to a larger diameter than the bucket. All loose material should be removed from the excavation.

Lining.

Pits should be lined or under some circumstances filled with stone larger than two inches in diameter. If a lining is used, the pit should be first backfilled with clean gravel to a depth of one foot above the pit bottom or one foot above the reamed ledge to provide a sound foundation. Preferred lining materials are clay or concrete brick, block, or rings. Rings should have weep holes or notches to provide for seepage. Brick and block should be laid dry with staggered joints. Standard brick should be laid flat to form a four-inch wall. The outside diameter of the lining should be at least six inches less than the least excavation diameter. The annular space formed should be filled with clean, coarse gravel to the top of the lining.

Pit Covers.

Either brick dome or flat concrete covers are satisfactory. They should be based on undisturbed earth and extend at least 12 inches beyond the excavation and should not bear on the lining for structural support. Bricks should be either laid in cement mortar or have a two-inch covering of concrete. If flat covers are used, a prefabricated type is preferred, and they should be reinforced to be the equivalent in strength of an approved septic tank cover. A nine-inch capped opening in the pit cover is convenient for pit inspection and for making connections to repair pits.

Connecting Lines.

Connecting lines should be of a sound durable material the same as used for the house to septic tank connection. Local experience with concrete tile, because of unusual soil or water characteristics, may dictate its judicious use. All connecting lines should be laid on a firm bed of undisturbed soil throughout their length. The grade of a connecting line should be at least two percent. The pit inlet pipe should extend horizontally at least one foot into the pit with a tee or ell to divert flow downward to prevent washing and eroding of the sidewalls. If multiple pits are used, or in the event repair pits are added to an existing system, they should be connected in series.

Backfilling.

All excavations should be backfilled as soon as possible after completion of construction, particularly to minimize the hazard of the excavation being used for dumping of trash. Backfill material should be free of large stones and trash should be well compacted and mounded a few inches higher than the natural ground surface.

Control and Inspection.

Assuming that a seepage pit has been properly designed and that desirable construction practices are defined, then administrative control remains a major item of consideration if successful results are to be realized.

It has been observed repeatedly in these studies that each installer and individual workman has his own opinion as to the proper design, construction, and operation of seepage pit systems. Some of the opinions are good, others are not. If individuals are left to their own devices, a variety of good and bad seepage pits result even if soils and standards are adequate. Training and instruction of persons concerned together with some system of inspection are essential.

Standardized pit construction and use of modern equipment simplifies control and inspection procedures. The fewer the types of excavating equipment, linings, and types of covers permitted, the fewer are the critical points of construction that must be checked. As pointed out previously, the wrong type and condition of excavating equipment can impair the quality of the pit. Appreciable control of this factor can be obtained by periodic inspection of equipment. If installer licensing is practiced, as in some areas, type and condition of equipment may be a requisite to renewal of the license. Control of quality of excavation through control of equipment would eliminate the need for the usual inspection during excavation. Requirement of even a brief pit log describing the soil strata would be desirable. It has been observed that a log can be checked with reasonable accuracy against observations of the excavated material at a later inspection.

Standardized construction also lends itself to simplified control which would insure use of quality materials. With a limited number of types of construction, material quality can be checked periodically at the installer's source or supply yard. One inspection of the actual system, at the time it is completed but not backfilled, to check workmanship and to assure compliance with design area and construction requirements should then be sufficient.

ACKNOWLEDGMENTS

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assisted in planning the studies and in the reviews of progress and results. Mr. James R. Simpson, Mr. Bernard T. Craun, and Mr. Elvin F. Henry of the Federal Housing Administration participated in meetings with the consultants.

During the investigation free access was available to the information developed in concurrent studies at the University of California under the direction of Professor P. H. McGauhey. This information aided in interpretation of data in this report.

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Seepage pits were investigated in eight counties in four different states. The cooperation and assistance of the state departments of health and the local health departments contributed heavily to the success of the endeavor. Because of their knowledge and experience with seepage pit systems, personnel of the state and local health departments provided invaluable assistance to the field investigators.

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APPENDICES

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Jefferson County, Kentucky

SUMMARY

Jefferson County is located in north central Kentucky on the Ohio River. The metropolitan complex of the City of Louisville is rapidly expanding to encompass the whole County. The continental-type climate is moderated by warm, moist air masses from the Gulf of Mexico. Temperatures either above 100 degrees or below 0 degrees are rare, and the mean annual rainfall is 43 inches.

Septic tank regulations are enforced by the well-organized Louisville-Jefferson County Health Department with specific control assigned to the Division of Environmental Health. The Department has permitted disposal of septic tank effluent to seepage pits in the alluvial deposits of the Ohio River for more than 30 years.

The typical seepage pit is 4 feet in diameter, 16 feet deep, and covered with a concrete slab. These pits are founded in caving sands, and precast concrete rings are used to form a lining. The final pit depth is attained by excavating inside of the rings and allowing them to slip downward.

Although Jefferson County was selected as a training ground, construction and soils data were obtained at 14 sites. A general survey of 69 homes was also completed to gather gross performance information. Two methods (a gross performance table and survival curves) were used to describe performance.

CONCLUSIONS

The following conclusions apply to the performance of seepage pits under the conditions of loading, design, and construction observed in Jefferson County, Kentucky:

1. The septic tank-seepage pit system is a suitable sewerage system for single-family residential homes.
2. Rapid horizontal changes in the physical characteristics of the alluvium make it impractical to attempt to derive a general design equation from the data collected at the 14 detailed study sites.

GENERAL INFORMATION

Jefferson County is located in north central Kentucky on the Ohio River. The residential and industrial areas of metropolitan Louisville encompass approximately one-half of the County's 375 square miles. The southwestern suburbs of Louisville are located on alluvium deposits of the Ohio River. This area, covering approximately 45 square miles, is commonly referred to as the "seepage pit area."

The population of Jefferson County has nearly doubled since 1930. The greatest increase has been in the residential suburbs of metropolitan Louisville. This growth is clearly illustrated in the results of the 1960 census which shows the population of metropolitan Louisville as 607,000, or 99 percent of the County's population.

Geology.

The geology of the Ohio River valley has been studied extensively.* The bedrock formations in Jefferson County are limestones, shales, and sandstones laid down in the Paleozoic era. The formations are generally uniform in thickness, with a dip of about 40 feet per mile to the west and southwest. The bedrock under the southwestern part of Louisville in the seepage pit area is shale. With the coming of the glaciers in the Pleistocene age, rivers flowing northwestward from the Appalachians were diverted into the Ohio River watershed. Subsequently, a river channel ranging from 25 to 100 feet deeper than the present channel was hewn into the bedrock. This channel was partially filled with alluvium when the glaciers melted and receded. The alluvium deposit in the seepage pit area has an average thickness of about 100 feet, with the present river channel entrenched 60 feet deep into this alluvium.

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*E. H. Walker, The Deep Channel and Alluvial Deposits of the Ohio Valley in Kentucky. Prepared in cooperation with the Agriculture and Industrial Development Board of Kentucky. U. S. Geological Survey Water Supply Paper 1411, 1957.

Soils and Topography.

In general, the soil of Jefferson County is representative of the gray-brown podsolic group. The soil in the seepage pit area is imperfectly developed silty clay to clay with very poor drainage. It is underlain by heterogeneous alluvial deposits. These alluvial deposits are composed of a heavy clay surface layer underlain by lenticular deposits ranging in texture from clay to gravel. The surface clay layer ranges up to 20 feet thick and the deposits below the 40-foot depth average less than 2 percent silt and clay.

There are three topographic patterns in Jefferson County. The eastern one-third of the County has a relatively rough topography and is characterized by broad ridges and numerous stream channels with gentle slopes. The larger streams have cut to 100 feet below the ridges. Another topographic pattern is located in the extreme southwest corner of the County. This topography, designated as "Knobs," is characterized by small hills rising abruptly 250 to 500 feet above a relatively level area. The topographic pattern of the central and north central part of the County and the Ohio River valley is more subdued. Elevations here range from 425 to 750 feet above sea level with a gentle slope from northeast to southwest.

Surface drainage is generally good in the rough topographic regions, but it is poor in the lowland and river valley area. Internal drainage of the soils is generally slow, particularly in the lowland area where surface ponding is common following heavy rainfall.

Ground Water.

The shallow soils and bedrock composed of shale, limestone, or sandstone have little storage capacity for water. Consequently, the water table undergoes extreme seasonal variation. Complete saturation of the overburden and topsoil is a frequent occurrence during wet seasons in areas underlain with shale. The water table in these same areas will recede to a considerable depth during the summer when evaporation and transpiration cause a soil moisture deficit.

The alluvial deposits in the Ohio River valley furnish a large and valuable source of ground water. A 1953 water resource study for the Louisville area* showed consumption at that time to be less than 10 percent of the potential supply. The chief source of recharge is the Ohio River which is connected directly to the ground water reservoir by coarse strata at the bottom of its channel.

Climate.

Jefferson County has a continental-type climate influenced by warm, moist air masses moving northward from the Gulf of Mexico, and cold arctic air coming from the north and west. It is not an extreme continental climate, and temperatures either above 100 degrees or below 0 degrees are rare. The mean rainfall of about 43 inches is evenly distributed throughout the year.

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*M. I. Rorabaugh, F. F. Schrader, and L. B. Laird, Water Resources of the Louisville Area Kentucky and Indiana. U. S. Geological Survey Circular 276, 1953.

Climatological data which may influence the operation of septic tank systems are summarized in Table 1. The wettest year on record occurred in 1950 when many of the systems included in the study were already in operation. Rainfall and temperature closely approximated the normal for the duration of the field study in the winter of 1956-1957.

Health Department Organization and Septic Tank Practice.

The Louisville-Jefferson County Health Department is a combined City-County unit. Jurisdiction over septic tank installation and design is assigned to the Division of Environmental Health. The septic tank program for Jefferson County comprises less than 10 percent of the Division's total work program.

Rigid septic tank control and inspection procedures were formulated in 1950. Since that time the Department has become increasingly stringent in the evaluation and acceptance of septic tank systems. Present controls are enacted jointly by the Jefferson County Planning Commission, the Louisville-Jefferson County Health Department, and the Jefferson County Building Department.

Control is instigated when proposed subdivision plans are submitted to the Planning Commission. The Planning Commission delegates the evaluation and approval of sewage disposal to the Health Department. The evaluation conducted by the Division of Environmental Health, includes use of percolation tests, visual inspection, and review of past performance on similar soils. Whenever possible, performance at homes on adjacent tracts is also reviewed to substantiate the findings of the field investigations.

Table 1

Summary of Climatological Data
Jefferson County, Kentucky*

Temperature, Precipitation, and Sunshine for Years of Record from 1906 to 1959

Season	Temperature, ^{o}F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	57	66	48	42.7	28.1	59.4	58
Winter (Dec.Jan.Feb.)	36	44	28	11.1	5.1	23.6	47
Summer (Jun.Jul.Aug.)	77	86	67	10.7	3.2	17.2	67

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, ^{o}F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1947-56	57	38	77	43.0	12.5	9.3
1952-56	58	39	78	37.5	10.7	7.5
Mar.'56-Feb.'57	57	39	75	35.5	8.4	9.0

*Weather Bureau Station at Standiford Field, Louisville, Kentucky.

Sewage disposal for individual homes, including those in approved subdivision tracts, must also be approved by the Health Department before the County Building Department or the State Plumbing Inspector's Office will issue their respective permits for construction. Actual inspection of individual systems is performed by personnel from the State Plumbing Inspector's Office.

Review of Health Department Records.

The Jefferson County Health Department has maintained a complete file of septic tank system applications and complaints since October 1949. The results of a review of this file are tabulated in Table 2. Approximately 25 percent of the installations have been seepage pit systems, while only 10 percent of the complaints relate to seepage pit systems. This ratio may be meaningful although field investigations have shown that the Health Department complaint file is not representative of true failure rates. A substantially large number of failing systems are repaired without notifying the Health Department.

Table 2

Tabulation of Septic Tank System
Applications and Complaints
Compiled From the Health Department Records
Jefferson County, Kentucky

Year	Septic Tank Applications			Septic Tank Complaints		
	Total	Seepage Pit	Percent Seepage Pit	Total	Seepage Pit	Percent Seepage Pit
1950*	1,462	262	18			
1951	1,220	157	13	91	6	7
1952	1,802	248	14	118	12	10
1953	2,916	765	26	112	10	9
1954	3,925	1,107	28	123	21	17
1955	4,749	1,358	29	186	8	4
1956	4,053	1,361	33	216	25	12
Total	20,127	5,258	25	846	82	10

*Includes Oct. 19, 1949 to Dec. 31, 1949.

RESULTS OF FIELD STUDIES

Jefferson County was selected as a training ground for new personnel assigned to the field studies. Its proximity to Cincinnati and the completeness of Health Department records provided an excellent opportunity to train personnel and develop field procedures. Two field teams received initial orientation during the three-months duration of the study. Tentative field procedures for general survey and detailed study examinations were developed under close supervision of the home office. General surveys at 69 homes and detailed studies at 14 homes were conducted in the "seepage pit" area.

Subdivision and Soil Descriptions.

The study area includes the subdivisions along the Dixie Highway between Algonquin Parkway and 7th Street Road. The homes in these subdivisions have 2 and 3 bedrooms and are located on lots ranging from 4,000 to 12,000 square feet in area. The oldest homes are about 30 years in age, while the development of new subdivisions is still in progress.

As was described previously, the soil is a silty clay to clay underlain by lenticular strata to a depth of 40 feet. Soils textural data collected at the 14 detailed study sites are summarized in Table 3. The test borings were approximately 16 feet deep, and the overburden of clay at these sites averaged 6 feet in depth.

Table 3

Detailed Soil Investigation Results
Jefferson County, Kentucky

Number of Tests	D_{10} mm*		D_{60} mm*		Uniformity Coefficient**	
	Mean	Range	Mean	Range	Mean	Range
14	.089	.012-.143	.246	.168-.332	3.9	2.2-14.0

*Percentile by weight. D_{10} and D_{60} are the particle diameters at which 10 and 60 percent of the sample will pass, respectively.

**The uniformity coefficient equals D_{60} divided by D_{10}.

Construction and Loading.

Septic tank-seepage pit system construction practices are uniform throughout the study area. The septic tanks are usually precast concrete with an operating capacity of 500 gallons; they have one compartment with baffles at the inlet and outlet. The general practice is to excavate the seepage pit by hand and line it with precast concrete rings. The rings over the lower portion of the excavation are either notched or provided with weep holes to insure free passage of the effluent. Solid rings are used over the upper portion of the excavation to prevent silt or clay from entering the pit. The average pit is 4 feet in diameter, 16 feet deep, and provides 150 square feet of usable sidewall area. Construction details for the 14 detailed studies are summarized in Table 4.

Loading factors which may influence septic tank system operation are also summarized in Table 4. The median person loading of 4.0 is approximately the national average, while the median water use of 6000 cubic feet per year is below average. Less than five percent of the homes surveyed were equipped with a food waste grinder, dishwasher, or water softener. Nearly all homes had clothes washers with approximately 50 percent of the machines being the automatic sequence type.

Table 4

Construction and Loading Data
Jefferson County, Kentucky

Item	No. of Obs.	Median	Range
System Age, Yrs.	69	7.0	2.5-19.8
Water Use, $Ft^3/Yr. \times 10^{-3}$ (Nov.Dec.Jan.Feb.)	14	6.0	4.0-10.0
Person Load, No.	62	4.0	2.0-7.0
Septic Tank Cap., Gals.	14	All 500	-
Pit Diameter, Ft.	14	All 4.0	-
Pit Depth, Ft.	14	16	13-20
Pit Sidewall Area, Ft^2	14	151	122-204

Gross Performance and Survival Curves.

The general survey data can be used to make a qualitative evaluation of performance. Data for this evaluation are summarized in Table 5. These data show that two-thirds of the systems investigated were performing satisfactorily at the time of the survey. The mortality-type survival curve, shown in Figure 1, relates the number of satisfactorily performing systems to the age of the system. This curve shows that 50 percent survival occurs at approximately 12 years. Calculations for the survival curve are presented in Table 6. Both the gross performance and survival curve evaluations are applicable only to systems with loading and construction features similar to the general survey sample.

Table 5

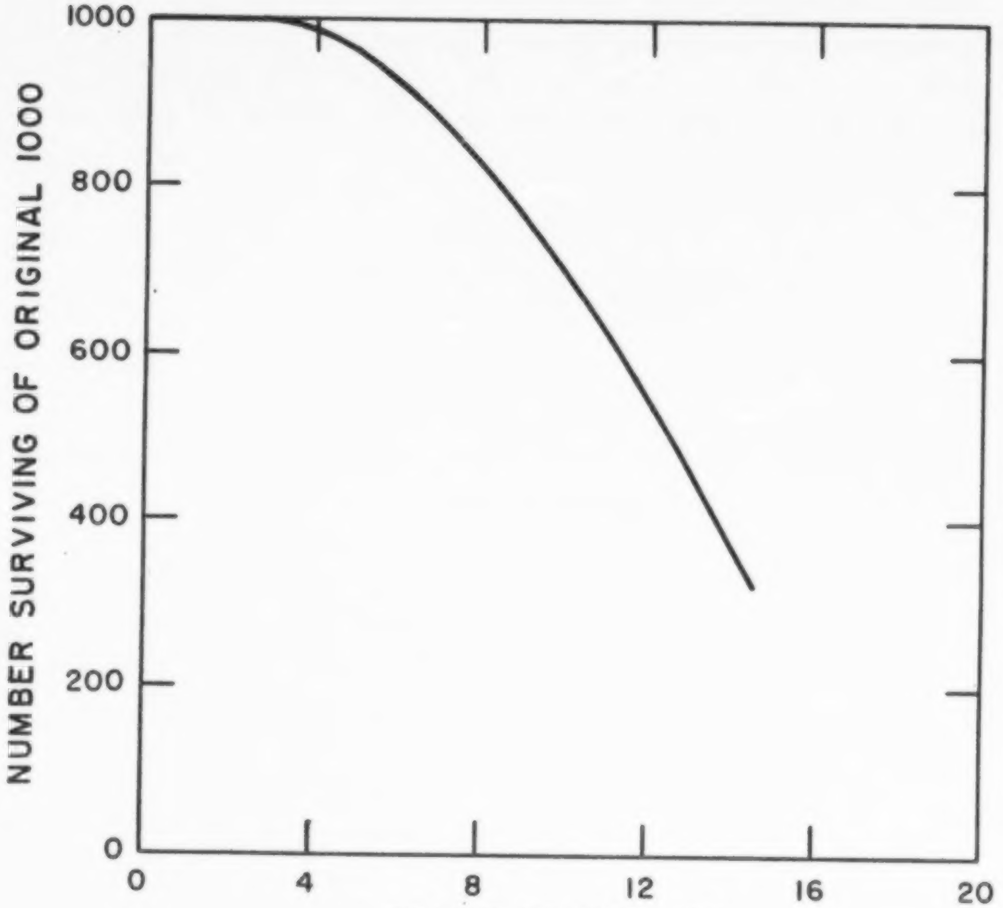
Gross Performance
Jefferson County, Kentucky

Years of Service		Mean Persons (No.)	Mean Sidewall Area (Ft^2)	No. of Obs.	Performance		
Mean	Range				No. Failed	No. Satisfactory	Percent Failed
7.4	2-20	3.8	156	69	23	46	33

Table 6

Survival Curve Calculations
Jefferson County, Kentucky

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
		General Survey			
0-1.9	69	0	.000	1000	0
2.0-3.9	69	0	.000	1000	0
4.0-5.9	64	5	.078	1000	78
6.0-7.9	41	7	.171	922	158
8.0-9.9	26	3	.115	764	88
10.0-11.9	19	4	.210	676	142
12.0-13.9	11	4	.363	534	194
14.0-15.9	6	0	.000	340	0
16.0-17.9	4	0	.000	340	0
18.0-19.9	1	0	.000	340	0



SURVIVAL CURVE
JEFFERSON COUNTY, KENTUCKY
FIGURE I

Table 7

Water Use Data
Jefferson County, Kentucky

All Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
852	4.0	5.0	166	8,600	52	.019
881	4.0	3.0	138	4,000	29	.034
851	4.2	2.0	151	4,000	26	.038
853	4.5	3.0	151	6,600	44	.023
825	5.0	4.0	122	6,000	49	.020
826	5.0	5.0	195	5,900	30	.033
827	5.0	-	122	5,400	44	.022
832	5.0	5.8	176	8,000	45	.022
823	6.5	5.0	176	8,300	47	.021
831	6.9	2.0	151	5,300	35	.028
829	7.0	4.0	126	5,800	46	.022
833	7.0	-	193	10,500	54	.018
830	8.0	4.0	204	7,600	37	.027
820	14.0	3.0	136	5,100	38	.027

*Derived from average winter (November, December, January, and February) use.

SECTION II

LOS ANGELES COUNTY,
CALIFORNIA

Los Angeles County, California

SUMMARY

Los Angeles County is the nucleus of a large metropolitan complex on the southwestern California coast which had a population of about 6,500,000 in 1960. The Pacific Ocean and mountain ranges produce variable climatic conditions ranging from a desert to mountainous areas receiving 30 inches of annual precipitation as rain and snow. The densely populated coastal areas have a mild climate with warm, dry summers and cool winters with occasional rain.

The Los Angeles County Health Department has a central office in the City of Los Angeles and Branch offices at strategic locations in the suburbs. Each branch unit has jurisdiction over a designated area.

Seepage pit construction is generally a highly mechanized operation. Excavations are made with truck-mounted, powered augers. Other specially designed equipment is used to aid in the installation of a porous lining. The typical pit is four feet in diameter and covered with a brick dome. Pit depth is governed by the soil formation encountered and ranges from 10 to 50 feet.

Soil textural data and seepage pit construction data were collected at 27 detailed study sites, and a general survey of 62 homes was conducted in the Point Dume area of Malibu Beach. Two methods (a gross performance table and survival curves) were used to describe performance for the Point Dume general survey.

CONCLUSIONS

The following conclusions apply to the use of seepage pits for the conditions of loading and construction observed in Los Angeles County, California:

1. The seepage pit is an adequate device for disposal of effluent when suitable methods are used to insure good design and construction.
2. One or more factors related to the age of the system have a strong influence on the performance of seepage pits at the homes surveyed in Point Dume.

GENERAL INFORMATION

Los Angeles County is located on the southwestern California coast, approximately 140 miles north of the Mexican border. It encompasses 4,071 square miles of land ranging from rugged desert mountains with 10,000-foot peaks, to a low, broad coastal plain along the Pacific Ocean.

The County had a population of approximately 490,000 in 1910, most of which was concentrated in the City of Los Angeles. The following 50-year span encompassed an industrial and population expansion far exceeding any conceivable prediction. The City of Los Angeles now has a population 4 times greater than the total County population of 1910, and the County population exceeded the 6,000,000 mark in the 1960 census.

Geology.

The detailed geology* of Los Angeles County is a complex system far beyond the scope of this paper. The northern and eastern geology is primarily a block fault mountain system of igneous and metamorphic rock. These mountains, the San Gabriel range, have peaks reaching 10,000 feet along the San Andreas fault. The streams from this mountain range empty into three major valleys. Two of these, the San Fernando and San Gabriel valleys, lie in Los Angeles County. These valleys are separated from the Pacific coast by a range of low hills approximately 15 miles from the coast. The coastal mountains are divided into several different ranges as the streams from the inland valleys pass through gaps en route to the ocean.

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*Harold C. Troxell, et al., Floods of March 1938 in Southern California, p. 322-339. U. S. Geological Survey Water Supply Paper 844, 1942.

The alluvial fans of the major streams have interconnected west of the low foothill ranges to form a broad, low flood plain approximately 50 miles long and 12 miles wide. The flood plain has a relatively uneven surface because of faulting and folding during recent land movements.

Soils and Topography.

Extreme climatic variability and intricate geological development have produced a complex soil system in Los Angeles County. Residual soils developed from sedimentary or igneous rock cover the greatest area. Alluvial soils are classified by relative age. One class, developed from older deposits, covers the coastal plain and portions of the interior valley slopes. The soils of this class exhibit a reasonably well-developed profile with distinct characteristics. The other alluvial soils occupy the present river flood plains and fans. They are distinguished from the older alluvial soils by the lack of a well-developed profile.

The County is divided into two major drainage basins by the San Andreas fault escarpment. The larger basin which drains to the Pacific Ocean in a southwesterly direction encompasses the San Fernando River and San Gabriel River valleys. The streams originate in deep "V" shaped canyons with steep gradients. The tributaries are numerous, producing a rugged topography. Stream gradients decrease rapidly in the valleys and basins causing the deposition of immense quantities of transported alluvium. The stream channels in the valleys are usually wide and shallow resulting in frequent overflow during flood periods. All streams are intermittent except for portions of the principal streams in the mountainous region.

Ground Water.

The older alluvial deposits and upper bedrock strata form an extensive water reservoir ranging up to 5000 feet in thickness. Many wells tapping the upper portion of this reservoir in the early 1900's had artesian flows. Withdrawal soon exceeded replenishment and salt water intrusion became a serious problem. Extensive studies have been conducted to evaluate and conserve this fresh water reservoir of the Los Angeles basin and coastal plains.

There is a relatively shallow reservoir of semiperched water in the recent alluvial deposits. This water reservoir is separated from the principal reservoir by impermeable strata, and it is not an important source of potable water.

Climate.

The influence of the Pacific Ocean, differences in elevation, and location of the mountain ranges cause vast differences in the climate of Los Angeles County. The annual precipitation ranges from a high of more than 30 inches in the mountains to 4 inches in the desert. Much of the precipitation in the mountains occurs as snow. In contrast, the coastal areas have an average frost-free season of more than 350 days.

Weather statistics for the City of Los Angeles, presented in Table 8, are representative of the densely populated areas in the County. A wet season starting in November and ending in April generally accounts for 90 percent of the mean annual rainfall. The summer months have virtually no rainfall, and they are characterized by clear, warm days.

Health Department Organization and Septic Tank Practice.

The Los Angeles County Health Department is composed of a central office and several branch offices. The central office is located in the City of Los Angeles, and the branch offices are in strategic locations throughout the County. Each office is a complete unit responsible for jurisdiction over a specified district. These districts encompass all unincorporated areas and those incorporated areas which do not maintain a controlling agency.

Minimum design requirements for household sewage disposal systems were initiated in 1933 under the Uniform Plumbing Code of the Western Plumbing Officials' Association. Chronological revisions of the minimum requirements since 1946 are summarized in Table 9.

Table 8

Summary of Climatological Data
Los Angeles County, California*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	63	73	53	15.0	4.1	31.3	78
Winter (Dec.Jan.Feb.)	56	66	47	8.1	1.2	20.1	76
Summer (Jun.Jul.Aug.)	70	80	59	0.1	0.0	0.6	83

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1947-56	61	54	67	9.5	5.9	0.0
1952-56	62	56	67	11.6	7.1	0.0
Apr.'56-Mar.'57	63	60	68	8.5	5.8	0.0

*Weather Bureau Station at Los Angeles International Airport, Los Angeles, California.

Table 9

Minimum Requirements for Septic Tank Systems
Los Angeles County, California

Period	Septic Tank Capacity (Gals.)	Seepage Pit Absorption Area Required
1946-1952	500	Four lineal feet of porous formation.
1952-1957	750	Four lineal feet of porous formation.

Septic tank system installation in Los Angeles County is controlled jointly by the Health Department and the Building Department. A sewage disposal system permit, issued by the Health Department, must be obtained before a building permit will be issued by the Building Department. The Health Department evaluates proposed septic tank system sites and recommends the type and size of system to be installed. Knowledge gained from previous experience is a valuable guide in making these recommendations. Actual inspection of septic tank systems is performed by the Building Department. Each installation is inspected after all work, except the final backfilling, has been completed.

Review of Health Department Records.

The Los Angeles County Health Department has participated in a sewer extension program for several years. In connection with this program, they have completed approximately 150 surveys. The surveys are conducted by sanitarians who visit homes to determine loading information, construction details, and septic tank system performance data. These surveys are similar to the general survey included in the field team's procedure; therefore, they were summarized as an additional source of general performance data. The result of this summary showing percentage of failure by age group is given in Table 10. These surveys were conducted in areas suspected of having difficulty with septic tank systems and represent performance on many soil types under a variety of loading and construction conditions.

Table 10

Summary of Surveys
Conducted by the Los Angeles County Health Department
Los Angeles County, California

Age (Yrs.)	No. of Systems	History No. Satisfactory	No. Failed	Percent Failed
0-5.0	1037	616	421	40
5.1-10.0	684	440	244	36
10.1-15.0	223	119	104	47
15.1-20.0	78	47	31	40
20.1-25.0	21	10	11	52
25.1-30.0	4	2	2	50
30.1-35.0	3	0	3	100

RESULTS OF FIELD STUDIES

The first member of a two-man field team was assigned to the area in January 1957. He was joined by an assistant in March, and the study continued through June when the field team was reassigned to Sacramento County, California. The field work completed in Los Angeles County is summarized in Table 11.

Table 11

Summary of Field Activities
Los Angeles County, California

Area	General Surveys	Detailed Studies	Total
Point Dume	61	1	62
San Fernando Valley	-	8	8
West Covina	-	6	6
Glendora	-	5	5
Miscellaneous	-	5	5
Total	61	25	86

Investigations in Los Angeles were completed early in the development of the Seepage Pit Study. The general survey and detailed study procedures used are relatively incomplete when compared to the procedures followed later in the study.

Subdivision and Soil Descriptions.

The general survey was conducted at Point Dume in Malibu Beach. The newer homes in the subdivision are six-room, three-bedroom ranches while the older homes vary in style and size. The soil in the Point Dume area is a sedimentary deposit ranging in texture from medium sand to very fine sand. The coarser textured strata are near the ground surface.

The detailed studies were conducted at various locations throughout the County, as shown in Table 11. Physical characteristics of the soil varied greatly from location to location. A summary of soils data collected is presented in Table 12.

Table 12

Detailed Soil Investigation Results
Los Angeles County, California

Number of Tests	D_{10} mm*		D_{60} mm*		Uniformity Coefficient**	
	Mean	Range	Mean	Range	Mean	Range
25	.063	.002-.340	.392	.0303-23.0	20.0	2.4-105

*Percentile by weight. D_{10} and D_{60} are the particle diameters at which 10 and 60 percent of the sample will pass, respectively.

**The uniformity coefficient equals D_{60} divided by D_{10}.

Construction and Loading.

Construction and loading factors which may affect system performance are summarized in Table 13. Seepage pit construction practice is relatively uniform. Special equipment is generally used for excavating. The pit is 4.0 feet in diameter and lined for structural stability, and the depth is governed by the soil strata encountered. A variety of septic tank designs with capacities of 550 gallons or more have been installed throughout the County.

Table 13

Construction and Loading Data
Los Angeles County, California

Item	Point Dume			Detailed Studies		
	No. of Obs.	Median	Range	No. of Obs.	Median	Range
System Age, Yrs.	62	1.6	0.3-10.0	25	4.5	1.9-10.0
Water Use, Ft^3/Yr. x 10^{-3} (Dec.Jan.Feb.)		No Data		23	15.0	9.8-23.3
Person Load, No.	58	3.0	1.0-8.0	19	4.0	2.0-5.0
Septic Tank Cap., Gals.	9	750	750-1650	23	810	550-1650
Pit Diameter, Ft.				27	4.0	4.0-4.5
Pit Depth, Ft.		No Data		27	19	11-45
Pit Sidewall Area, Ft^2				27	188	85-332

Loading data for the Point Dume general survey, as well as the detailed studies, are summarized in Table 13. It should be noted that age distribution is skewed toward the younger systems in the general survey. The younger homes are larger and approximately twice as many are equipped with food waste grinders. The percentage of homes with other appliances such as dishwashers, water softeners, and clothes washers is not related to the skewness in system age.

Gross Performance and Survival Curves.

Performance for the general survey systems appears to be affected by some factor associated with the skewed distribution of system age. The data in Table 14 have been classified to coincide with the change in building practice that resulted in the skewed age. The older system group has apparently performed more satisfactorily than the younger group. This difference in performance for the two age groups is shown graphically in the survival curve presented in Figure 2. Calculations for the survival curve are shown in Table 15. The skewed distribution of system age is also demonstrated in this Table.

The difference in performance can be accounted for in part by the lesser person loading for the older systems, Table 14. It is also possible that differences in construction practice, provided soil area, or soil absorption capacity may have contributed to the observed difference in performance.

Table 14

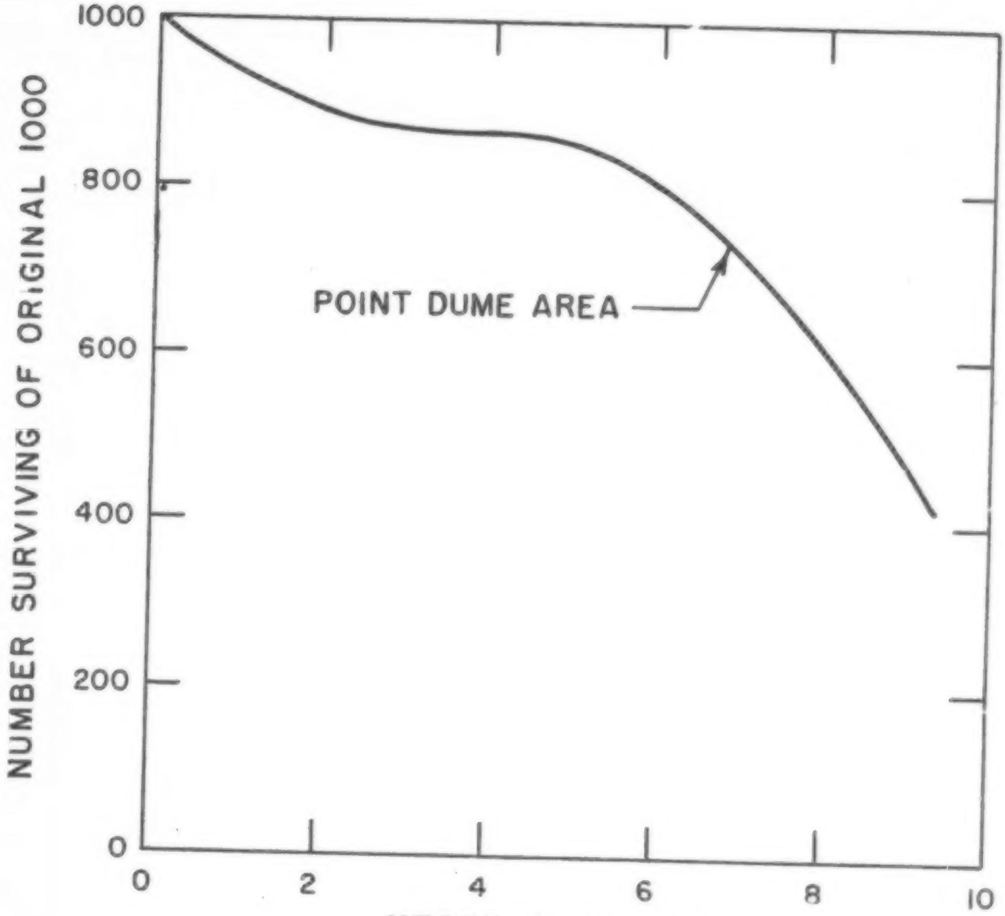
Gross Performance
Los Angeles County, California

Location	Years of Service		Mean Persons (No.)	No. of Obs.	Performance		
	Mean	Range			No. Failed	No. Satis-factory	Percent Failed
Point Dume							
< 4.0 Yrs.	1.5	0.3-3.0	3.5	49	7	42	14
> 4.0 Yrs.	5.2	4.0-10.0	2.7	13	3	10	23

Table 15

Survival Curve Calculations
Los Angeles County, California

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
		Point Dume			
0-0.9	62	4	.0645	1000	64
1.0-1.9	51	2	.0392	936	37
2.0-2.9	28	1	.0357	899	32
3.0-3.9	17	0	-	867	-
4.0-4.9	14	0	-	867	-
5.0-5.9	11	1	.0909	867	79
6.0-6.9	7	0	-	788	315
7.0-7.9	5	2	.400	788	-
8.0-8.9	3	0	-	473	-
9.0-9.9	2	0	-	473	-
10.0-10.9	2	0	-	473	



SURVIVAL CURVE

LOS ANGELES COUNTY, CALIFORNIA

FIGURE 2

Table 16

Water Use Data
Los Angeles County, California

All Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
744	1.0	-	150	18,900	126	.008
731	1.5	5.0	233	17,400	74	.013
757	1.9	5.0	332	19,000	57	.017
736	2.0	4.0	85	17,500	206	.011
746	2.0	5.0	148	14,000	94	.010
734	2.7	4.0	175	9,800	56	.018
737	2.8	5.0	175	14,500	82	.012
732	3.5	4.0	257	18,700	72	.014
748	3.6	2.0	175	13,400	75	.013
743	3.6	2.9	287	18,300	64	.016
758	3.7	-	188	16,100	86	.012
749	3.9	4.7	104	11,300	108	.009
735	4.0	5.0	188	17,100	91	.011
745	4.0	3.0	192	16,300	84	.012
747	5.0	4.0	196	11,700	60	.016
754	5.5	3.7	290	15,600	54	.015
755	5.6	3.5	240	12,700	52	.018
753	5.8	3.5	240	10,300	42	.023
733	7.0	2.0	130	12,900	99	.010
752	7.5	4.5	131	13,500	103	.010
750	7.7	-	117	13,000	11	.009
740	8.5	-	287	23,300	81	.012
730	9.0	4.0	116	10,100	87	.012

*Derived from average winter (December, January, and February) use.

SECTION III

SANTA CLARA COUNTY,
CALIFORNIA

Santa Clara County, California

SUMMARY

Santa Clara County, located at the southern tip of San Francisco Bay, is rapidly developing into a large metropolitan area. The County population of 642,000 in the 1960 census is a sevenfold increase since 1930. The influence of the surrounding mountains and the Pacific Ocean results in a mild climate with dry summers and a short, wet season in the winter.

The County has a well-organized Health Department with jurisdiction over all unincorporated areas, and those incorporated areas which do not have a controlling agency. Rigid septic tank regulations covering subdivision tracts and individual homes are enforced by the Division of Sanitation. Because of hazards to ground water seepage pits were banned as a general device for disposal of sewage in December 1951.

The typical seepage pit installed in Santa Clara County from 1947 to 1951 was 4 feet in diameter, about 12 feet deep, and covered with a concrete slab or redwood planks. It was lined with radial, concrete block specially designed for this purpose.

Comprehensive construction details and soils textural data were collected at 21 sites. In addition 97 homeowners in 3 subdivision tracts were interviewed to obtain general performance data. Three methods (a gross performance table, survival curves, and a mathematical model) are employed to describe the performance of seepage pits.

CONCLUSIONS

The following conclusions apply to the performance of seepage pits under the conditions of loading and construction observed in Santa Clara County, California:

1. Although protection of the ground water reservoir makes it necessary to prohibit the use of seepage pits, they are suitable devices for disposing of effluent in the type of soil formation encountered.

2. Parameters derived from the field data and an average home occupancy of four persons were used to derive a general design equation for the alluvial deposits found in Loree Estates and El Quito Park. This equation is:

$$A = 22.8\ t$$

where:

A is the square feet of pit sidewall area needed, and
t is the years of expected service.

3. An economic analysis shows that minimum costs are obtained with a design area of 319 square feet resulting in a renewal period of 14 years.

GENERAL INFORMATION

Santa Clara County encompasses 1328 square miles of west central California at the southern tip of San Francisco Bay. It is widely known for its rich agricultural soils. These rich soils in the northern half of the County are rapidly becoming subdivision tracts as the southern shoreline of the Bay is being developed into a large metropolitan area. San Jose with a population of 204,000 is the largest incorporated city.

Population growth in the County has increased at a phenomenal rate since the early 1940's. The greatest growth has occurred in the smaller incorporated communities. These rapidly expanding communities such as Los Altos, Saratoga, Sunnyvale, and Los Gatos are located in the northwestern part of the County. Population growth in this metropolitan area mushroomed from 90,000 in 1930 to 602,000 in 1960.

Geology.

The geologic history of the Santa Clara Valley is punctuated by alternating periods of uplift and submergence.* Severe faulting, folding, and erosion occurred during the periods of uplift. The bedrock, 5000 feet below the surface at San Jose, is composed of marine and fresh water sediments laid down in the early and pre-Pliocene era. The surface deposits of the Valley floor are primarily recent alluvial fan, flood plain, and tideland deposits.

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*Flood Problems in Santa Clara County, California, p 56-59. County of Santa Clara Planning Commission, Monograph No. 3, 1952.

The alluvial fan deposits are found at the mouths of the many intermittent streams around the perimeter of the Valley. The flood plain deposits are found farther out on the Valley floor, and the tideland deposits are along the shore of San Francisco Bay. The three types of deposits form irregular, semicircular bands from the mountain perimeter to the Bay.

Soils and Topography.

The soils in the Valley are divided into four physiographic divisions* as follows: (1) alluvial fan and flood plain soils, (2) basin soils, (3) terrace soils, and (4) upland soils. These divisions are directly related to geological formations.

The alluvial fan and flood plain soils, developed on the recent alluvial deposits, have no clay accumulation in the subsoil. They occupy approximately one-third of the Valley floor.

The basin soils are on the recent tideland deposits adjacent to the present tidal flats. They are heavy textured and poorly drained. Slopes are very slight and some of the soils are alkali.

The terrace soils are subdivided into high terrace and low terrace soils. Both are located on the remnants of older valley fill material, but the high terrace soils exhibit a more fully developed profile. These soils are generally medium textured with moderately dense to dense subsoils.

*Soils of Santa Clara County, California. University of California, Agricultural Experiment Station, February 1947.

The upland soils are on the mountain slopes, and they are derived in place from weathering of much older geological formations. They are generally medium to heavy textured soils with a relatively shallow profile. The slopes are steep and severe erosion is common.

The Valley floor is nearly level and it is rare to have slopes of more than three percent. The slopes change rapidly over a short distance as one approaches the encircling mountains. Although the mountains have a rounded, smooth topography, the slopes are steep, reaching more than 45 percent in some cases. Numerous streams with highly irregular flow intensity empty into the Valley from these mountains.

The internal drainage of the soil is directly related to the geologic history of the Valley. The soils on sedimentary deposits near the Bay have poor internal drainage; the soils on alluvial and flood plain deposits adjacent to the sedimentary deposits have good internal drainage; and the mountain slope soils are intermediate between these two.

Ground Water.

Two important structural features produce a large underground reservoir in the Santa Clara Valley. Extensive alluvial gravel deposits are found at depths of 1000 to 4000 feet. These deposits, as well as the water-bearing rock structure, have a gentle dip from the sides of the Valley toward the center. Blue clay strata, generally encountered at a depth of 300 feet, form an impermeable horizontal barrier over these water aquifers, preventing the infiltration of salt water into the reservoir. The reservoir is replenished by stream and rainfall infiltration through gravel strata in the foothills around the perimeter of the Valley. This reservoir is the primary source of all domestic and irrigation water used in the Valley, and rigid controls are enforced to prevent its contamination.

Limited supplies of potable water are also found in gravel strata above the blue clay formation. Many relatively shallow wells which were drilled into these aquifers are still in operation. They furnish domestic supplies for low density building outside the defined service areas of the large public water systems.

Climate.

The climate of Santa Clara County is greatly affected by the surrounding mountains and proximity of the Pacific Ocean. The mountains have the greatest influence on the annual precipitation, while the ocean has the greatest influence on the temperature.

Mean annual rainfall for the urban area of the County ranges from a low of 14 inches at San Jose to a high of 30 inches at Los Gatos in the western foothills. The winters are characteristically wet with most of the annual precipitation coming from November through April. Mean annual temperatures range from 52.4 degrees at Lick Observatory to 58.4 degrees at Gilroy. The average growing season at eight recording stations in the County ranges from 246 to 331 days with a mean of 280 days for the whole County.

Health Department Organization and Septic Tank Practice.

The Santa Clara County Health Department has jurisdiction in all of the incorporated area (except the Cities of San Jose and Alviso) as well as the unincorporated areas of the County.

Rigid septic tank ordinances were formulated in 1947. These ordinances placed land development with septic tank systems under the close supervision of the County Health Officer, Building Inspector, and Planning Commission. Separate approval procedures were developed for individual installations and subdivisions.

Individual installations are handled through the Health Department. An individual must present a septic tank permit from the Health Department to obtain a building permit from the Building Inspector. This septic tank permit, issued by the Sanitation Division, includes a plot plan which provides for an adequate septic tank system. On-site inspection and percolation tests may be required to evaluate the proposed system plan.

Subdivision approval is handled by a Planning Commission Subcommittee composed of representatives from the County Engineers, Health Department, and Planning Commission. This Subcommittee must give unanimous approval of the proposed subdivision before it is submitted to the County Board of Supervisors for final approval. Each member works only with the phases of the subdivision development which come under the jurisdiction of his department.

Review of Health Department Records.

A permanent file of all septic tank system installations since March 1947 has been maintained by the Health Department. More than 20,000 systems, including 2,000 septic tank-seepage pit systems, were installed from 1947 to 1956. The seepage pit systems were installed prior to 1951 when the seepage pit was banned as a general method for effluent disposal.

The Health Department conducted several surveys in the 1950's to evaluate septic tank system performance. The surveys were of a general nature aimed at ultimate extension of sanitary sewers to the surveyed area. A summary of these surveys, shown in Table 17, indicates seepage pits performed as well as absorption fields.

Table 17

Frequency of Failure for County Health Department Sewer Surveys Santa Clara County, California

	Septic Tank-Absorption Field Systems				Septic Tank-Seepage Pit Systems			
Age at Time of Survey	No. of Systems	History		Cumulative Percent Failed	No. of Systems	History		Cumulative Percent Failed
		Satisfactory	Failed			Satisfactory	Failed	
0.0-2.9	75	56	19	3	3	2	1	2
3.0-5.9	213	166	47	11	17	11	6	11
6.0-8.9	240	198	42	19	32	28	4	17
9.0-11.9	39	28	11	21	11	9	2	21
Total	567	448	119		63	50	13	

RESULTS OF FIELD STUDIES

Field studies were conducted in Santa Clara County from March 15 to June 15, 1957. These studies are summarized in Table 18.

Table 18

Summary of Field Activities
Santa Clara County, California

Area	General Surveys	Detailed Studies	Total
Loree Estates	51	6	57
El Quito Park	27	3	30
Lovell Avenue	19	2	21
Miscellaneous	0	10	10
Total	97	21	118

Subdivision and Soil Descriptions.

Loree Estates is located southwest of Santa Clara near the intersection of Stevens Creek Road and Lawrence Station Road in Cupertino. It is a subdivision of 7- to 10-year old, 2- and 3-bedroom homes. It is a large subdivision which had been sewered prior to the date of the survey. A large percentage of homeowners had not connected to the sewers and a random sample was chosen from this group for the general survey. The surface soil is poorly drained and unsuitable for the use of tile absorption fields, but it is overlying a coarse, permeable alluvium with excellent absorption characteristics.

The whole area is level and the lots are a uniform 75 by 125 feet. The yards are generally well maintained, although many homeowners have fenced off part of the back yard which they do not maintain in lawn.

El Quito Park is located between Santa Clara and Saratoga at the intersection of Saratoga Avenue and Quito Road. Development of the subdivision was rapid and the range in house age is small. The ranch style, 3-bedroom homes are located on lots of 10,000 square feet. Generally, the entire lot was maintained in lawn with numerous shrubs and trees. It is a large subdivision and homes were chosen randomly for the general survey. The soil ranges from loam to gravelly fine sandy loam. The subsoil is a coarse alluvial deposit similar to the formation in Loree Estates. The general terrain is relatively level to gently rolling with slopes over five percent uncommon. The subdivision area was leveled, leaving only the necessary slope to provide for surface runoff.

The Lovell Avenue area is a part of the San Quino Tract, located between Campbell and Los Gatos, west of Santa Clara-Los Gatos Road. It is a small subdivision of 9- to 10-year old, 2-bedroom homes. The soil in the area is gravelly loam which is underlain by an alluvial deposit generally coarser in texture than was observed in Loree Estates and El Quito Park. The original terrain was level with gently sloping small ridges which were leveled in the process of subdividing. The lots are relatively large, averaging 14,000 square feet with a 70-foot frontage. Yard maintenance varies from excellent to fair.

Detailed studies conducted in the three general survey subdivisions show that the soil in the Lovell Avenue area is coarser in texture than the soil in El Quito Park and Loree Estates. Two detailed studies conducted in the Lovell Avenue area exhibit four feet of coarse strata in a pit seven feet deep. The 9 detailed studies conducted in Loree Estates and El Quito Park have less than 4 feet of coarse strata in pits averaging 15 feet in depth. Measured soil textural parameters, summarized in Table 19, are significantly different for the two areas.

Construction and Loading.

Similar seepage pit construction practices were followed in Loree Estates and El Quito Park, while a somewhat different procedure was used in the Lovell Avenue area. Pits in the former two subdivisions were augered with special equipment and lined with concrete block designed to fit the excavation. Pits in the latter area were excavated with a backhoe. A cylindrical brick lining was constructed, and excavated soil was used to backfill around the lining. All septic tanks were of similar design and capacity. The typical tank is 3 by 9 feet with a liquid depth of 4 feet and an operating capacity of 810 gallons. Approximately two-thirds of the total capacity is in the first two compartments. Pertinent construction data are summarized in Table 20.

Loading data which may influence septic tank system performance are also shown in Table 20. Systems in Loree Estates and El Quito Park have a greater person load than those in the Lovell Avenue area. The Lovell Avenue area systems are substantially older than those in Loree Estates and El Quito Park.

Table 19

Detailed Soil Investigation Results
Santa Clara County, California

Survey Unit	Number of Tests	D_{10} mm*		D_{60} mm*		Uniformity Coefficient**	
		Mean	Range	Mean	Range	Mean	Range
Loree Estates and El Quito Park	9	.009	.001-.036	.787	.048-2.32	106	24.0-271
Lovell Avenue	2	.171	.062-.280	7.99	7.04-8.94	72.7	31.9-113.5
Miscellaneous	10	.040	.001-.215	2.06	.054-10.4	150	28.5-642

*Percentile by weight. D_{10} and D_{60} are the particle diameters at which 10 and 60 percent of the sample will pass, respectively.

**The uniformity coefficient equals D_{60} divided by D_{10}.

Table 20

Construction and Loading Data
Santa Clara County, California

Item	Loree Estates and El Quito Park			Lovell Avenue		
	No. of Obs.	Median	Range	No. of Obs.	Median	Range
System Age, Yrs.	87	6.9	5.0-8.8	21	8.8	8.8-10.0
Water Use, $Ft^3/Yr. \times 10^{-3}$ (Dec.Jan.Feb.)	9	8.7	6.1-16.1	2	12.0	7.2-17.1
Person Load, No.	53	4.0	2.0-5.8	11	3.0	2.0-6.0
Septic Tank Cap., Gals.	87	All 810	-	21	All 810	-
Pit Diameter, Ft.	87	All 4.2	-	21	All 5.0	-
Pit Depth, Ft.	68	16	10-27	2	7	7-8
Pit Sidewall Area, Ft^2	25	156	103-256	2	71	62-80

Many modern household appliances discharge waste which may affect the loading of septic tank systems. Data for a number of these appliances are summarized in Table 21. The percentage of homes with food waste grinders or dishwashers is very small in both survey areas. Homes with water softeners occur more frequently. In general, the regeneration wastes from the water softeners are not discharged to the septic tank system. Nearly all homes were equipped with clothes washers, and the relative distribution of manual and automatic units was similar for the two survey areas.

Table 21

Household Appliances
Santa Clara County, California

Appliance	Percentage of Homes with Appliance	
	Loree Estates and El Quito Park	Lovell Avenue
Food Waste Grinder	3	5
Dishwasher	3	5
Water Softener	29	10
Clothes Washer	96	100
Manual	18	24
Automatic	52	62
History of Both	26	14

Gross Performance and Survival Curves.

The general survey data can be used to make a qualitative evaluation of performance for the two soil formations. Data for this evaluation are summarized in Table 22. Performance is substantially better in the Lovell Avenue area which has a coarser textured subsoil. Systems in the Lovell Avenue area have a 25 percent greater mean age and 40 percent less usable sidewall area, yet they have performed more satisfactorily than systems in Loree Estates and El Quito Park. It is not probable that the lesser person loading for Lovell Avenue could account for this indicated difference in performance.

Another method of qualitative comparison is the mortality-type survival curves shown in Figure 3. These curves also show that performance in the Lovell Avenue area is substantially better. The effect of system age is eliminated in this approach, but the differences in loading and usable sidewall area influence the interpretation of the curves. Again, it is improbable that the difference in loading could account for the indicated difference in performance as well as the known difference in sidewall area. Calculations for the survival curves are presented in Table 23.

Table 22

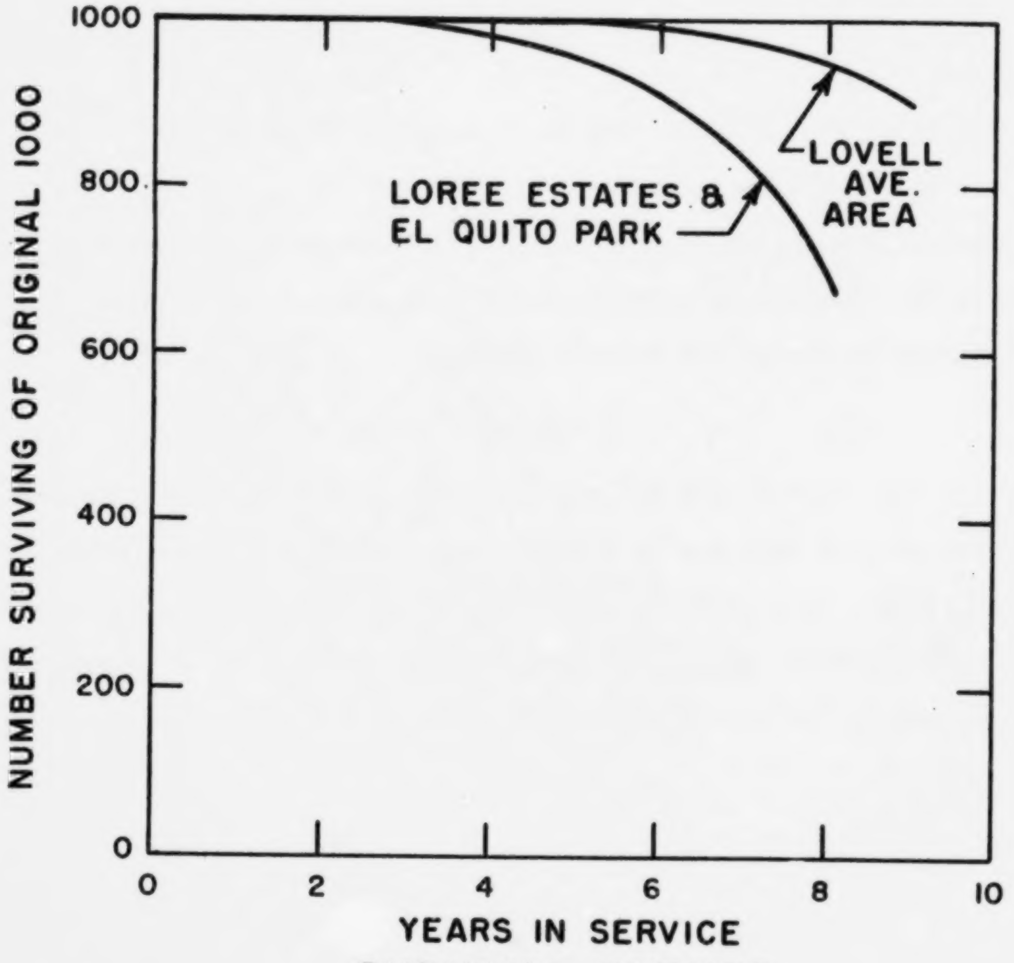
Gross Performance
Santa Clara County, California

Area	Years of Service		Mean Persons (No.)	Mean Sidewall Area (Ft^2)	No. of Obs.	Performance		
	Mean	Range				No. Failed	No. Satis-factory	Percent Failed
Loree Estates and El Quito Park	7.0	2.5-8.8	3.9	153	87	21	66	24
Lovell Avenue	8.8	6.7-9.3	3.4	92	21	2	19	10

Table 23

Survival Curve Calculations
Santa Clara County, California

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
Loree Estates and El Quito Park					
0-0.9	87	0	.0000	1000	-
1.0-1.9	87	0	.0000	1000	-
2.0-2.9	87	1	.0114	1000	11
3.0-3.9	86	1	.0116	989	11
4.0-4.9	85	1	.0118	978	12
5.0-5.9	84	4	.0476	966	45
6.0-6.9	79	7	.0886	921	80
7.0-7.9	34	7	.206	841	172
8.0-8.9	5	0	-	669	-
9.0-9.9	0	-	-	-	-
Lovell Avenue					
0-0.9	21	0	-	1000	-
1.0-1.9	21	0	-	1000	-
2.0-2.9	21	0	-	1000	-
3.0-3.9	21	0	-	1000	-
4.0-4.9	21	0	-	1000	-
5.0-5.9	21	0	-	1000	-
6.0-6.9	21	1	.0476	1000	48
7.0-7.9	20	0	-	952	-
8.0-8.9	20	1	.0500	952	48
9.0-9.9	4	0	-	904	-
10.0-10.9	0	0	-	-	-



SURVIVAL CURVES

SANTA CLARA COUNTY, CALIFORNIA

FIGURE 3

INTERPRETATION OF RESULTS

A mathematical model* has been derived which can be applied to the field data to determine a design equation for soil absorption area. This equation expresses the relationship between the soil absorption area required, A, for a given period of operation, t, with a loading factor, Q, as:

$$A = \frac{Q}{kL} + \frac{Qt}{L} \tag{1}$$

where:

k is the rate reaction constant of interface clogging, and

L is the ultimate interface absorption capacity.

Wetted sidewall area, person loading, and years of successful service, as measured in the field, can be substituted for A, Q, and t, respectively. Dividing through by person load produces equation:

$$\frac{A}{P} = \frac{1}{kL} + \frac{1}{L}\,t \tag{2}$$

which is a linear equation with an intercept of $\frac{1}{kL}$ and a slope of $\frac{1}{L}$. The data presented in Table 24 were used to derive a design equation for Loree Estates and El Quito Park. Data available for the Lovell Avenue area are not sufficient to develop an equation. Assuming an average home occupancy of four persons, the design equation for Loree Estates and El Quito Park is:

$$A = 22.8\ t$$

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*Study of Seepage Beds. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, December 15, 1960.

An economic analysis procedure[*] has been developed to determine the optimum design area and renewal period for a given period of operation. Assuming a desirable operating period of 30 years, the optimum design area for Loree Estates and El Quito Park is 319 square feet with a renewal period of 14 years.

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*Harold A. Thomas, James B. Coulter, T. W. Bendixen, and Allan B. Edwards, Technology and Economics of Household Sewage Disposal Systems. Journal Water Pollution Control Federation, February 1960.

Table 24

Apparent Loading Rate Data
Santa Clara County, California

Loree Estates and El Quito Park - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
544	2.5	3.9	185	.021	47.5
534	5.0	5.7	130	.044	22.5
552	5.4	4.4	106	.042	24.1
562	5.5	5.0	144	.035	29.0
582	6.4	5.1	103	.050	20.0
587	6.4	5.2	113	.046	21.9
543	6.8	3.8	170	.022	44.8
583	6.8	3.0	134	.022	44.5
551	7.0	4.4	138	.032	31.0
554	7.0	5.0	156	.032	31.2
555	7.0	4.0	202	.020	50.4
548	7.5	4.9	256	.019	51.9
553	7.6	5.3	164	.032	30.9
556	7.8	2.6	199	.013	76.7

Table 24 (Continued)

Loree Estates and El Quito Park - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
585	6.8	3.2	168	.019	55.8
505	7.3	3.2	111	.029	34.4
507	7.5	5.0	115	.043	23.0
506	7.8	2.0	135	.015	67.4
502	7.8	3.0	75	.040	24.9
503	7.8	2.2	59	.037	26.9
508	7.8	2.8	92	.030	32.3
501	8.8	2.8	183	.015	64.5
Lovell Avenue - All Failed Systems					
610	6.7	6.0	80	.075	13.3
609	8.6	3.1	62	.050	20.0

SECTION IV

SACRAMENTO COUNTY,

CALIFORNIA

Sacramento County, California

SUMMARY

Sacramento County is located in the San Joaquin Valley approximately 90 miles northeast of San Francisco. Rapid suburban development north of Sacramento, the state capital, is largely responsible for the fivefold increase in the County's population from 1920 to 1960. The climate is characterized by a long, dry summer and a short, cool winter.

The Division of Sanitation of the Sacramento County Health Department enforces regulations which control the use of septic tank systems. Control and inspection procedures were modified considerably in the early 1950's to keep pace with the explosive urban expansion.

Seepage pit design requirements are adapted to mechanized construction practices. In general, the pits are excavated with power equipment, backfilled with cobblestones, and covered with a concrete slab. A relatively small number of seepage pits installed in the early 1950's were lined with a redwood casing.

A percolation test procedure, patterned after that used by the County Health Department, was developed as a part of the study in this area and included in the soil investigations conducted at the 27 detailed study sites. The percolation test procedure developed here was also used in all subsequent study areas. All detailed studies were conducted at homes where a lined seepage pit had been installed. Three methods (a gross performance table, survival curves, and a mathematical model) were used to evaluate performance.

CONCLUSIONS

The following conclusions apply to the use of lined seepage pits under the conditions of loading and construction observed in Sacramento County, California:

1. The seepage pit, when properly designed, is a suitable device for the disposal of effluent.

2. Parameters derived from the field data and an average home occupancy of four persons were used to derive a general design equation for the soil formation found in Casa Bella Park and Orangevale. This equation is:

   $$A = 53.6t$$

   where:

   A is the square feet of pit sidewall area needed per home, and
   t is the years of expected service.

3. An economic approach showed that minimum costs are obtained with a design area of 536 square feet resulting in an optimum renewal period of 10 years.

GENERAL INFORMATION

Sacramento County is located 90 miles northeast of San Francisco in the northern extension of the Great Central valley. The County covers 985 square miles bordering the western foothills of the Sierra Nevada range. Its major population center, the City of Sacramento, is the state capital as well as the county seat. Urban development is rapidly spreading throughout the northern section of the County as the suburbs of Sacramento have experienced extremely rapid growth since the early 1940's. The 1960 County population of 500,000 is 5 times the County population of 1920.

Geology.

Sacramento County extends from the Sacramento River on the west to the foothills of the Sierra Nevada range on the east. In early geologic time the valley area underwent long periods of alternate sedimentary deposition, folding and faulting, and volcanic activity. In recent times the area has received extensive deposition of alluvium from the western slopes of the Sierra Nevada.

Erosion during recent geologic time accompanied by periods of folding and uplifting of the Sierra Nevada range, resulted in the formation of three distinct alluvial plains during the Pliocene and Pleistocene epochs. These plains are represented by the Laguna, Arroyo Seco, and Victor formations.*
The Laguna and Arroyo Seco formations are deposits of gravel, sand, and clay, while the Victor formation is composed of gravel, sand, and silt.

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*Denton W. Carlson, Mines and Mineral Resources of Sacramento County, California, vol. 51, No. 2, p. 117-199. California Journal of Mines and Geology, April 1955.

Soils and Topography.

The soils of Sacramento County can be divided into four physiographic groups associated with the various parent materials.* These groups are: (a) soils of the uplands developed from weathering of bedrock and clay, (b) soils developed on flood plains and recent alluvial fans, (c) soils developed on old alluvial plains and terraces, and (d) soils developed in alluvial basins. The upland soils are found on sloping to steeply sloping hills in the foothills of the Sierra Nevada range. They are generally shallow, stony soils. The flood plain and recent alluvial soils are highly stratified soils that do not exhibit profile development. Many of these soils are subject to intermittent flooding from the adjacent streams. The older alluvial soils are the most extensive soils in the County, covering more than 50 percent of the total area. They are identified by a characteristic indurated hardpan at an average depth of approximately two feet. Basin soils occupy low lying areas along the major streams. They have a moderately developed profile, and they are relatively high in organic matter content.

The topography ranges from undulating hilly land in the eastern part of the County to relatively level land throughout the central and western sections. The general slope is from northeast to southwest toward San Pablo Bay and San Francisco Bay. Natural drainage ranges from good to poor moving across the County from east to west. The poorly drained western area depends on a system of ditches for drainage. Since many of these ditches are below the river level, pumps are used to lift water over levees into either the Sacramento River or various sloughs which are connected to the Sacramento River.

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*Walter W. Weir, Soils of Sacramento County, California. University of California, Agricultural Experiment Station, April 1950.

Ground Water.

There is an extensive ground water body underlying all of Sacramento County at depths ranging from 20 feet below the ground surface near the Sacramento River to 150 feet below the ground surface in the eastern part of the County. This ground water body is of excellent quality and is used extensively for irrigation purposes. The northeastern section of the County in the foothills of the Sierra Nevada range has a perched water body above the main reservoir. This perched water is shallow, ranging from less than 25 feet up to 75 feet below the ground surface. Both ground water bodies are recharged primarily by runoff from melting snow in the high Sierra Nevada range.

Climate.

The climate in Sacramento County is characterized by hot, dry summers and cool winters. Periods of prolonged light rainfall in the winter months account for most of the average annual precipitation of 18 inches. Snow seldom falls in the valley, and melts rapidly when it does. The average growing season is 308 days, from February 2 to December 11. Weather data which may affect septic tank system operation are presented in Table 25.

Table 25

Summary of Climatological Data
Sacramento County, California*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	60	72	49	18.2	6.7	34.7	82
Winter (Dec.Jan.Feb.)	48	55	40	10.3	2.0	22.2	53
Summer (Jun.Jul.Aug.)	73	88	57	0.2	0.0	1.3	95

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1948-57	61	47	73	18.5	10.3	0.2
1953-57	61	48	73	18.0	10.6	0.3
Jan.'57-Dec.'57	61	48	73	18.4	9.7	0.0

*Weather Bureau Station at Municipal Airport, Sacramento, California.

Health Department Organization and Septic Tank Practice.

The Division of Sanitation of the Sacramento County County Health Department is responsible for septic tank control and inspection. The County is divided into several sections by size and population density. One sanitarian is assigned to each section and he is responsible for septic tank control in this section as well as many other environmental health duties.

The Sacramento County Health Department began control of septic tank system installation in November 1940. Regulatory control has increased greatly with the explosive urban expansion since 1950. At the present time the Health Department has requirements governing subdivision tract approval, as well as regulations specifying the type, design, and size of systems installed at individual homes. The present minimum sewage disposal system shall consist of a 1000-gallon septic tank and if seepage pits are utilized and the lot is not part of a subdivision, a 36-inch-diameter pit per bedroom is required. Pits may be landed no closer than 10 feet to an aquifer. The Health Department and FHA jointly developed a percolation test for subdivision evaluation.

The Health Department also establishes sewage disposal requirements for commercial and industrial establishments and public and private schools with the concurrence of the California State Regional Water Pollution Control Board.

Review of Health Department Records.

The Health Department maintains several files relating to septic tank systems. One of these is an alphabetical file of engineers' reports for subdivisions started after January 1955. These reports contain a plat of the subdivision, boring logs for test holes, textural analyses of permeable strata, percolation test data, and a recommendation of soil area needed for successful operation.

Permit files are maintained for all septic tank system construction. These files, summarized in Table 26, include permits issued for absorption field systems, seepage pit systems, and additions to existing systems.

Table 26

Seepage Pit Installations and
Septic Tank System Repairs from 1953 to 1957
Sacramento County, California

Item	1953	1954	1955	1956	1957**	Totals
New Seepage Pit Permits Issued	472	1524	3042	2740	780	8558
Repair Seepage Pit Permits Issued*	428	1196	404	584	472	3084

*Includes Seepage Pit permits issued for repair of absorption fields.

**Through July.

RESULTS OF FIELD STUDIES

Field studies were conducted in Sacramento County from June to December 1957. A percolation test procedure was added to the detailed study procedure prior to commencing actual field studies. A summary of field activities is presented in Table 27.

Table 27

Summary of Field Activities
Sacramento County, California

Area	General Surveys	Detailed Studies	Total
Casa Bella Park	8	12	20
Arden Glen	-	7	7
Orangevale	-	7	7
Miscellaneous	-	1	1
Total	8	27	35

Subdivision and Soil Descriptions.

Orangevale and Casa Bella Park subdivisions are located in the northeastern residential suburbs. The average house in these areas has six rooms, two or three bedrooms, and one bath. Arden Glen is located south and west of the above subdivisions. The average house in this subdivision has six rooms, three bedrooms, and two baths.

The subsoil in Orangevale and Casa Bella Park is the Laguna formation, while the subsoil in Arden Glen is the Victor formation. A summary of soils data collected at the detailed study sites is presented in Table 28. Since Orangevale and Casa Bella Park were located on similar deposits of the Laguna formation, data for these subdivisions were combined for further analyses.

Construction and Loading.

Construction and loading factors which may affect septic tank performance are shown in Table 29. Seepage pit construction features were similar in both survey locations. The pits were 2.7 feet in diameter and lined with a 20-inch square, redwood casing. The annular void around the casing was backfilled with 1½- to 2-inch gravel. Median septic tank capacity, person load, and system age are also the same for both locations.

Many modern household appliances may affect the loading of septic tank systems. Data for several of these appliances are shown in Table 30. No homes with dishwashers were surveyed in either area. Food waste grinders and water softeners were not common in Casa Bella Park and Orangevale, but about 50 percent of the homes in Arden Glen have these appliances. Nearly all homes were equipped with clothes washers.

Gross Performance and Survival Curves.

The general survey data can be employed to make qualitative evaluation of system performance. The data presented in Table 31 and Figure 4 show a slight advantage in performance for systems in Arden Glen. Calculations for the survival curves in Figure 4 are presented in Table 32. The data for Arden Glen are based on a relatively small sample and it is possible that a larger number of observations would produce radically different results.

Table 28

Detailed Soil Investigation Results
Sacramento County, California

Area	Number of Tests	D_{10} mm*		Percolation Rate**		Slope Factor***		Visual Permeability Rating****	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Casa Bella Park and Orangevale	19	.081	.004-.204	.013	.0002-.042	.004	.001-.009	3.2	2.1-3.8
Arden Glen	7	.043	.023-.072	.053	.018-.072	.044	.009-.160	3.4	3.1-3.8

*Percentile by weight. D_{10} is the particle diameter at which 10 percent of the sample will pass.

**Percolation rate in gal./ft^2/min. at a head equal to the depth of ponding in the existing seepage pit for the slowest percolation run.

***A plot of $\frac{1}{H}$ (head in ft.) vs. Σt (hrs.) for the percolation test produces a straight line with slope m. The slope factor equals $m \frac{D}{4}$ where D equals the pit diameter.

****Average value weighted for thickness of strata and based on a scale where: 1 = excellent, 2 = good, 3 = fair, and 4 = poor.

Table 29

Construction and Loading Data
Sacramento County, California

Item		Casa Bella Park and Orangevale	Arden Glen
Number of Observations		19	7
System Age, Yrs.			
	Median	3.6	3.6
	Range	1.6-5.7	3.3-3.6
Person Load, No.			
	Median	4.0	4.0
	Range	1.8-6.6	2.7-5.0
Septic Tank Cap., Gals.			
	Median	1000	All 1000
	Range	1000-1650	
Pit Diameter, Ft.			
	Median	All 2.7	All 2.7
	Range		
Pit Depth, Ft.			
	Median	20	21
	Range	15-38	20-22
Pit Sidewall Area, Ft^2			
	Median	167	177
	Range	116-326	163-185

Table 30

Household Appliances
Sacramento County, California

Appliance	Percentage of Homes with Appliance	
	Casa Bella Park and Orangevale	Arden Glen
Food Waste Grinder	7	57
Dishwasher	0	0
Water Softener	0	43
Clothes Washer	100	86
Manual	22	0
Automatic	60	57
History of Both	18	29

Table 31

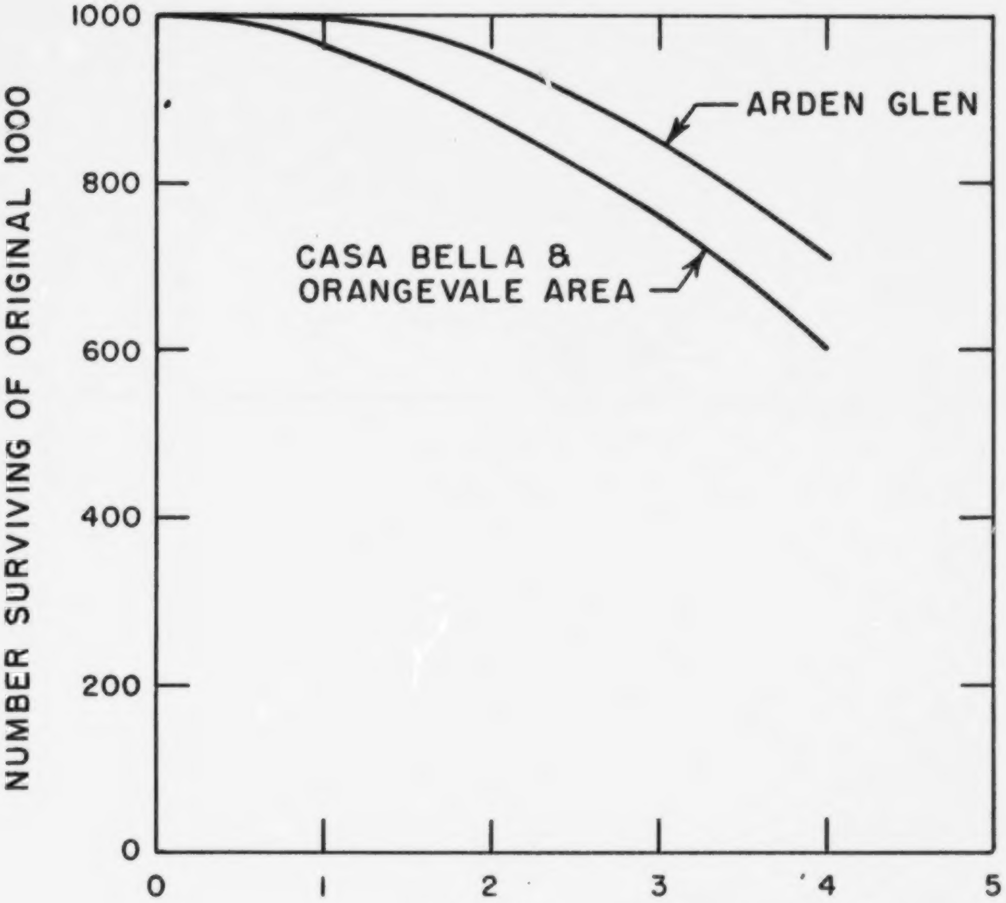
Gross Performance
Sacramento County, California

Area	Years of Service		Mean Persons (No.)	Mean Sidewall Area (Ft^2)	No. of Obs.	Performance		
	Mean	Range				No. Failed	No. Satisfactory	Percent Failed
Casa Bella Park and Orangevale	3.2	1.6-4.9	3.9	188	27	12	15	44
Arden Glen	3.3	2.8-3.6	4.0	175	7	2	5	29

Table 32

Survival Curve Calculations
Sacramento County, California

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
		Casa Bella Park and Orangevale			
0-0.9	27	1	.037	1000	37
1.0-1.9	26	2	.077	963	74
2.0-2.9	23	4	.174	889	154
3.0-3.9	18	3	.166	735	122
4.0-4.9	3	2	.667	613	408
5.0-5.9	0	0	-	205	-
		Arden Glen			
0-0.9	7	0	.000	1000	-
1.0-1.9	7	0	.000	1000	-
2.0-2.9	7	1	.143	1000	143
3.0-3.9	6	1	.167	857	143
4.0-4.9	0	0	-	714	-



SURVIVAL CURVES

SACRAMENTO COUNTY, CALIFORNIA

FIGURE 4

130

INTERPRETATION OF RESULTS

A mathematical model* has been derived which can be applied to the field data to determine a design equation for soil absorption area. This equation expresses the relationship between the soil absorption area required, A, for a given period of operation, t, with a loading factor, Q, as:

$$(1) \qquad A = \frac{Q}{kL} + \frac{Q}{L}t$$

where:

k is the rate reaction constant of interface clogging, and

L is the ultimate interface absorption capacity.

Wetted sidewall area, person loading, and years of successful service, as measured in the field, can be substituted for A, Q, and t, respectively. Dividing through by person load produces equation:

$$(2) \qquad \frac{A}{P} = \frac{1}{kL} + \frac{1}{L}t$$

which is a linear equation with an intercept of $\frac{1}{kL}$ and a slope of $\frac{1}{L}$. The data presented in Table 33 were used to derive a design equation for Casa Bella Park and Orangevale. Data available for the Arden Glen area are not sufficient to develop an equation. Assuming an average home occupancy of four persons, the design equation for Casa Bella Park and Orangevale is:

$$A = 53.6t$$

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*Study of Seepage Beds. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, December 15, 1960.

An economic analysis procedure* has been developed to determine the optimum design area and renewal period for a given period of operation. Assuming a desirable operating period of 30 years, the optimum design area for Casa Bella Park and Orangevale is 536 square feet with a renewal period of 10 years.

*Harold A. Thomas, James B. Coulter, T. W. Bendixen, and Allan B. Edwards, Technology and Economics of Household Sewage Disposal Systems. Journal Water Pollution Control Federation, February 1960.

Table 33

Apparent Loading Rate Data
Sacramento County, California

Casa Bella Park and Orangevale - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
650	2.1	4.0	128	.031	32.0
652	2.2	4.0	149	.027	37.2
651	2.7	4.0	222	.018	55.5
672	2.7	4.0	116	.034	29.0
654	3.0	5.0	272	.018	54.4
685	3.6	4.7	222	.021	47.2
684	3.8	5.0	230	.022	46.0
682	3.8	1.8	185	.010	101.3
683	4.9	2.0	133	.015	66.5
Casa Bella Park and Orangevale - Successful Systems					
656	1.6	3.9	94	.041	24.0
670	2.6	4.0	115	.035	28.8
655	3.4	3.6	134	.027	37.3
671	3.4	2.3	172	.013	73.5
659	3.5	6.6	126	.052	19.0
657	3.6	5.1	96	.053	18.8
653	3.7	3.0	87	.034	29.0
658	3.7	5.0	176	.028	35.1
681	3.7	3.0	173	.018	57.7
680	3.9	3.5	132	.026	38.0

Table 33 (Continued)

Arden Glen - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
678	2.9	5.0	163	.031	32.6
675	3.6	4.0	177	.022	44.2

Arden Glen - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
676	3.3	2.7	74	.036	27.4
679	3.4	4.7	107	.044	22.6
677	3.6	3.2	87	.037	27.2
674	3.6	3.3	149	.022	45.4
673	3.6	4.0	131	.030	32.8

SECTION V

FRESNO COUNTY,
CALIFORNIA

Fresno County, California

SUMMARY

Fresno County is located in the central part of the San Joaquin Valley. The climate is characterized by dry, hot summers and moderate winters with an average frost-free season of 291 days.

The County is divided into districts for control purposes by the Division of Sanitation of the Fresno County Health Department. A sanitarian with full responsibility for environmental sanitation is assigned to each district. His duties include enforcement of regulations governing installation of septic tank systems.

Seepage pit construction practices have been adapted to take full advantage of mechanized installation. Truck-mounted, powered augers are used to excavate for the septic tanks and seepage pits. The typical pit is 4 feet in diameter, 15 to 20 feet deep, and covered with a brick dome. It is either brick-lined or filled with cobblestones to provide structural stability.

A total of 37 septic tank-seepage pit systems in two alluvial soil deposits was studied in detail. In addition, 184 homeowners were interviewed to obtain gross performance data. Three methods (a gross performance table, survival curves, and a mathematical model) were used to evaluate the observed performance.

CONCLUSIONS

The following conclusions apply to the use of seepage pits under the conditions of loading and construction observed in Fresno County, California:

1. The seepage pit, when properly constructed, provides a suitable method for disposal of effluent.

2. Parameters derived from the field data and an average home occupancy of four persons were used to derive general design equations for two soil formations. The equation for the alluvial parent material of the ferrosol soils is:

   $$A = 22.4\ t$$

   and the equation for the alluvial parent material of the brown alluvial soils is:

   $$A = 28.2\ t$$

   where:

   A is the square feet of pit sidewall area needed per home, and
   t is the years of expected service.

3. An economic approach showed that minimum costs are obtained with a design area of 314 square feet in the ferrosol soil area and 367 square feet in the brown alluvial soil area. These design areas result in renewal periods of 14 and 13 years, respectively.

GENERAL INFORMATION

Fresno County, covering 5985 square miles, bisects the San Joaquin Valley from east to west. The only large metropolitan area is the City of Fresno which is centrally located on U. S. Highway 99.

The substantial increase in the County population is primarily due to rapid growth in metropolitan Fresno where the population has tripled during the last three decades. This metropolitan area is defined to include suburban developments within five miles of the Fresno city limits. The 1960 metropolitan area population of 213,000 is approximately double the entire County population of 1930.

Geology.

Fresno County extends across the California trough, and the eastern and western boundaries of the County lie in the Sierra Nevada and Coastal Range mountains, respectively. These mountains are primarily granitic rock of Mesozoic age.

The California trough is filled with deep alluvial deposits transported from the Coastal Range and Sierra Nevada mountains. The more extensive deposits come from the Sierra Nevada mountains whose streams have a greater and steadier flow than their counterparts from the arid eastern slopes of the Coastal Range. These recent deposits are poorly stratified, and horizontal differences in composition are rapid over relatively short distances.

Soils and Topography.

Excluding the mountain ranges, the soils of Fresno County are members of the pedocals. More specifically, the soils in the vicinity of Fresno are calcic to noncalcic brown alluvial or calcic to noncalcic brown ferrosol.

The brown ferrosols are characterized by a shallow, red-iron hardpan of variable depth and thickness. In some instances there is considerable lime in the hardpan. These ferrosols are found in the northwestern part of Fresno commonly referred to as the "fig gardens."

The brown alluvial soils exhibit a friable, permeable loam profile which becomes lighter with increasing depth. They have developed on recent alluvium which overlies the older parent material of the ferrosols. The typical ferrosol hardpan may still be encountered at much greater depths. These recent alluvial deposits are present throughout the Fresno area with the exception of the "fig gardens."

The general topography is smooth-surfaced alluvial fans extending westward from the Sierra Nevada mountains. These alluvial fans with moderate slopes are much more extensive than those from the Coastal Range and reach to the foothills of the Coastal Range in some cases. The steeper alluvial fans from the Coastal Range extend only a short distance into the Valley along its western border.

Ground Water.

The extensive alluvial deposits form a large, natural reservoir. This reservoir is recharged annually by runoff from melting snow in the Sierra Nevada mountains. The Fresno municipal water supply is taken from this reservoir by numerous wells. The depth to the water table ranges from 30 to 70 feet in the metropolitan area.

Climate.

Fresno has a dry, arid climate with a mean annual rainfall of less than 10 inches. The summers are characterized by dry, clear days providing a high potential evapotranspiration, and winters are mild with infrequent cold spells. The average growing season is 291 days with the first killing frost in the latter part of November and the last killing frost near the end of March. Pertinent weather data are presented in Table 34.

Health Department Organization and Septic Tank Practice.

Septic tank system installation in Fresno County is under the jurisdiction of the Division of Sanitation of the Fresno County Health Department. The County is divided into districts with one sanitarian assigned to each district. This sanitarian is responsible for all environmental sanitation within his assigned district.

Available septic tank system regulations date back to 1945. The recommendations at that time specified an 810-gallon, two-compartment septic tank with a 4-foot diameter seepage pit 15 feet deep. The seepage pit recommendation was increased to two pits 20 feet deep in April 1953 with the maximum penetration at least 10 feet above the water table. Another change came in March 1954 when the practice of installing a porous lining was abandoned in favor of a rock backfill. After three years of unsatisfactory experience with rock-filled pits their use has been abandoned and brick-lined pits are now required.

Table 34

Summary of Climatological Data
Fresno County, California*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	63	76	50	9.6	5.9	17.8	82
Winter (Dec.Jan.Feb.)	48	57	39	4.9	1.1	9.8	63
Summer (Jun.Jul.Aug.)	79	96	62	0.1	0.0	1.7	96

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1948-57	62	47	77	10.0	5.2	0.1
1953-57	62	47	76	9.6	5.4	0.2
Jan.'57-Dec.'57	62	47	78	10.0	5.2	0.2

*Weather Bureau Station at Fresno Air Terminal, Fresno, California.

A large percentage of home building in metropolitan Fresno is done under the auspices of the Federal Housing Administration. Their minimum septic tank system requirements from April 1953 to the time of the study are shown in Table 35. The FHA and the Fresno County Health Department also have a cooperative procedure for evaluation of proposed subdivision tracts. This procedure includes extensive testing of the subsoil and locating the ground water table.

Table 35

Summary of FHA Minimum Requirements for Septic Tank Systems Taken from the April 1953 Revision of the Minimum Property Requirements for the State of California

Septic Tank		Seepage Pit	
Number of Bedrooms in Home	Tank Capacity (Gals.)*	Character of Soil	Required Area**
2	500	Coarse sand or gravel	30
3	600	Fine sand	45
4	750	Sandy loam or sandy clay	75
5	900	Clay with small amount of sand or gravel	240
		Heavy tight clay, hardpan, rock, or other impervious formation	Unsuitable

*Increase capacity by 50 percent when a food waste grinder is installed.

**Square feet of wall area per bedroom.

Review of Health Department Records.

Available Health Department records were reviewed to obtain general information which would aid in selecting detailed study sites. Information on septic tank installations and repairs was incomplete; therefore, these data were not tabulated.

In 1953 the Health Department surveyed 187 homes in a subdivision located in the brown alluvial soil area. The survey showed that approximately 15 percent of these 3- to 4-year old systems had not performed satisfactorily.

RESULTS OF FIELD STUDIES

Field studies were conducted in Fresno County from June through December 1957. The study procedure at this time was directed toward obtaining a maximum number of detailed studies. The general survey technique was used only as an aid to locate suitable detailed study sites. A summary of the field work is presented in Table 36.

Table 36

Summary of Field Activities
Fresno County, California

Soil	Homeowners Interviewed	Detailed Studies	Total
Ferrosol	36	13	49
Brown Alluvial	124	21	145
Miscellaneous	24	3	27
Total	184	37	221

Subdivision and Soil Descriptions.

The data collected in Fresno came from several subdivisions with a variety of home styles and sizes. The systems selected can be considered as a representative cross section of moderately priced suburban development in the Fresno area.

The data have been classified into two groups according to the nature of the soil. One group, designated as ferrosol soil, includes those sites selected in the "fig garden" area. The other group, designated as brown alluvial soil, includes all other sites in metropolitan Fresno. These soils are underlain by alluvial deposits of different composition.

Soils data for the two alluvial deposits are summarized in Table 37. These data show that the parent material of the ferrosol soil is coarser textured and absorbs fresh water at a faster rate than that of the brown alluvial soil.

Construction and Loading.

Construction and loading data which may influence septic tank system performance are shown in Table 38. Seepage pit construction details were similar for all systems. The pits were augered with special equipment and lined with porous brick or concrete for structural stability. Pits in the ferrosol group had less usable sidewall area than those in the brown alluvial group. In general, the septic tanks were vertical cylinders with two compartments.

Data for modern household appliances which may affect septic tank loading are presented in Table 39. There is an appreciably greater percentage of food waste grinders and dishwashers in the ferrosol group. The percentage of clothes washers and relative distribution of manual and automatic sequence units are similar for both units.

Table 37

Detailed Soil Investigation Results
Fresno County, California

Soil	Number of Tests	D_{10} mm*		Percolation Rate**		Slope Factor***		Visual Permeability Rating****	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range
Ferrosol	13	.100	.012-.219	.213	.038-.598	.158	.012-.541	2.7	2.2-3.1
Brown Alluvial	21	.058	.016-.130	.054	.003-.187	.024	.002-.091	3.1	1.8-3.7
Miscellaneous	3	.065	.005-.103	.121	-	.062	.025-.100	3.1	2.6-3.8

*Percentile by weight. D_{10} is the particle diameter at which 10 percent of the sample will pass.

**Percolation rate in gal./ft^2/min. at a head equal to the depth of ponding in the existing seepage pit for the slowest percolation run.

***A plot of $\frac{1}{H}$ (head in ft.) vs. Σt (hrs.) for the percolation test produces a straight line with slope m. The slope factor equals $m \frac{D}{4}$ where D equals the pit diamter.

****Average value weighted for thickness of strata and based on a scale where: 1 = excellent, 2 = good, 3 = fair, and 4 = poor.

Table 38

Construction and Loading Data
Fresno County, California

Item		Ferrosol	Brown Alluvial
Number of Observations		12	21
System Age, Yrs.			
	Median	7.0	6.5
	Range	4.6-8.5	3.2-11.7
Person Load, No.			
	Median	3.0	3.9
	Range	2.3-5.0	2.0-7.0
Septic Tank Cap., Gals.			
	Median	1000	1000
	Range	810-1650	810-1650
Pit Diameter, Ft.			
	Median	4.0	4.0
	Range	4.0-4.2	3.1-4.2
Pit Depth, Ft.			
	Median	11	15
	Range	9-14	11-20
Pit Sidewall Area, Ft^2			
	Median	103	150
	Range	89-134	90-389

Table 39

Household Appliances
Fresno County, California

Appliance	Percentage of Homes with Appliance	
	Ferrosol	Brown Alluvial
Food Waste Grinder	17	5
Dishwasher	33	10
Water Softener	0	0
Clothes Washer	100	95
Manual	17	5
Automatic	67	62
History of Both	16	28

Gross Performance and Survival Curves.

The loading data collected during homeowner interviews can be combined with the detailed study construction data to qualitatively evaluate performance. These data, summarized in Table 40, show that systems in the ferrosol group have performed more satisfactorily. Person load and percentage of failure are similar in both soil areas. Years of service is 17 percent greater and sidewall area is 33 percent less in the ferrosol soil than in the brown alluvial soil.

The mortality-type survival curves shown in Figure 5 provide a second qualitative estimate of performance for systems in the two soil formations. The curves show that approximately 50 percent of the systems in both groups performed satisfactorily for 8 or more years. The curves cannot be employed to rank the two soil formations because the provided absorption area is significantly less for the systems in the ferrosol group. Calculations for the survival curves are presented in Table 41.

It should be noted that these curves are derived primarily from data collected at homes three or more years old. Therefore, they depict performance for systems installed prior to the changes in seepage pit construction requirements made in 1953 and 1954.

Table 40

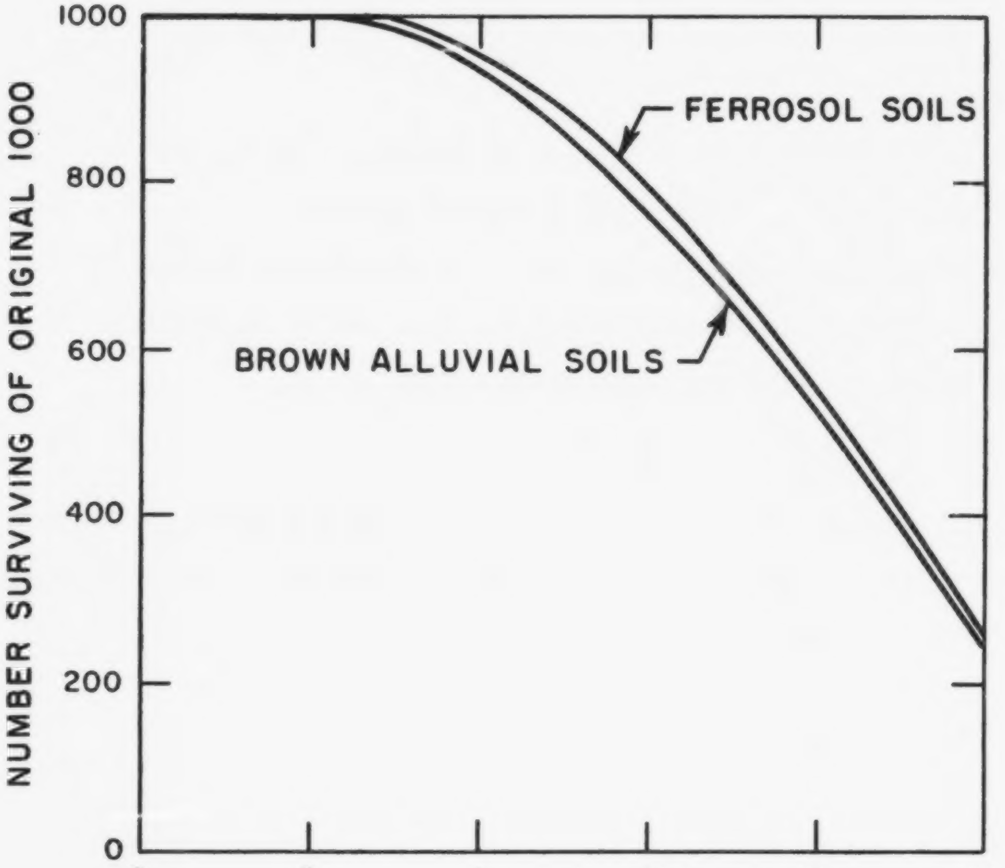
Gross Performance
Fresno County, California

Soil	Years of Service		Median Persons (No.)	Median Sidewall	No. of Obs.		Performance	
	Median	Range		Area (Ft^2)		No. Failed	No. Satisfactory	Percent Failed
Ferrosol	7	2-11	4	106	36	13	23	36
Brown Alluvial	6	1-11	4	159	124	47	77	38

Table 41

Survival Curve Calculations
Fresno County, California

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
Ferrosol Soils					
0-0.9	36	0	.000	1000	0
1.0-1.9	36	0	.000	1000	0
2.0-2.9	36	0	.000	1000	0
3.0-3.9	35	0	.000	1000	0
4.0-4.9	29	1	.034	1000	34
5.0-5.9	25	5	.200	966	193
6.0-6.9	19	5	.263	773	203
7.0-7.9	7	0	.000	570	0
8.0-8.9	4	2	.500	570	285
9.0-9.9	2	0	.000	285	-
10.0-10.9	2	0	.000	285	-
Brown Alluvial Soils					
0-0.9	124	0	.000	1000	0
1.0-1.9	124	0	.000	1000	0
2.0-2.9	121	0	.000	1000	0
3.0-3.9	118	4	.034	1000	34
4.0-4.9	91	10	.110	966	106
5.0-5.9	69	13	.188	860	162
6.0-6.9	54	6	.111	698	77
7.0-7.9	40	5	.125	621	78
8.0-8.9	23	8	.348	543	189
9.0-9.9	6	1	.167	354	59
10.0-10.9	2	0	.000	295	0
11.0-11.9	0	-	.000	295	0



SURVIVAL CURVES

FRESNO COUNTY, CALIFORNIA

FIGURE 5

INTERPRETATION OF RESULTS

A mathematical model[*] has been derived which rationally expresses the operation of a soil absorption system. This equation denotes the relationship between the soil absorption area required, A, for a given period of operation, t, with a loading factor, Q, as:

$$A = \frac{Q}{kL} + \frac{Q}{L}t \qquad (1)$$

where:

k is the rate reaction constant of interface clogging, and

L is the ultimate interface abosprtion capacity.

Wetted sidewall area, person loading, and years of successful service, as measured in the field, can be substituted for A, Q, and t, respectively. Dividing through by person load produces equation:

$$\frac{A}{P} = \frac{1}{kL} + \frac{1}{L}t \qquad (2)$$

which is a linear equation with an intercept of $\frac{1}{kL}$ and a slope of $\frac{1}{L}$. The data presented in Table 42 were used to derive design equations for the two general soil formations. These equations are:

Ferrosol Soil $A = 22.4\ t$

Brown Alluvial Soil $A = 28.2\ t$

---

[*] Study of Seepage Beds. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, December 15, 1960.

These equations are applicable to the parent materials of these soils in the Fresno area. Ferrosol or brown alluvial soils in other locations may have radically different parent materials; therefore, the equations are not general design equations for these soils.

An economic analysis procedure* has been developed to determine the optimum design area and renewal period for a given period of operation. Using this procedure, a 30-year period of operation, and cost data collected at the time of the study, the optimum areas and renewal periods are:

	Optimum Area (Ft^2)	Renewal Period (Yrs.)
Ferrosol Soil	314	14
Brown Alluvial Soil	367	13

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*Harold A. Thomas, James B. Coulter, T. W. Bendixen, and Allan B. Edwards, Technology and Economics of Household Sewage Disposal Systems. Journal Water Pollution Control Federation, February 1960.

Table 42

Apparent Loading Rate Data
Fresno County, California

Reference No.	Time in Swc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
Ferrosol Soils - Failed Systems					
693	3.3	5.0	134	.037	26.8
713	3.5	2.6	98	.026	38.1
706	4.4	3.0	97	.031	32.3
715	4.9	4.0	74	.054	18.6
691	5.7	2.9	128	.022	44.0
702	6.3	4.6	89	.052	19.2
700	6.4	4.0	109	.037	27.2
716	7.2	3.0	103	.029	34.3
Ferrosol Soils - Successful Systems					
705	6.7	3.0	123	.024	41.0
712	6.9	3.6	131	.027	36.3
717	7.3	2.8	93	.030	33.4
714	7.8	2.3	103	.022	44.4
Brown Alluvial Soils - Failed Systems					
701	4.2	3.1	112	.028	36.4
709	4.7	4.8	121	.040	25.0
707	5.2	5.1	154	.033	30.0
696	5.5	2.0	90	.022	45.0

Table 42 (Continued)

Brown Alluvial Soils - Failed Systems
(Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
711	5.5	2.3	134	.017	58.3
718	5.8	4.6	166	.028	35.8
726	5.8	4.3	198	.053	45.9
694	6.3	3.0	131	.023	43.5
699	6.3	2.3	167	.014	72.9
725	6.5	3.5	183	.019	52.9
695	6.8	6.7	174	.038	25.8
708	7.5	3.9	168	.023	43.2
710	7.5	2.9	139	.021	47.9

Brown Alluvial Soils - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Load Rate Pers/Ft^2/Yr.	Reciprocal Load Rate Ft^2/Pers x Yrs.
723	3.2	7.0	113	.062	16.2
722	3.7	4.6	122	.038	26.2
719	4.2	5.1	150	.034	29.6
724	4.2	4.0	164	.024	41.0
703	6.3	2.0	95	.021	47.5
704	6.3	2.0	88	.023	44.0
721	6.8	5.0	128	.039	25.6

SECTION VI

SAN DIEGO COUNTY,
CALIFORNIA

San Diego County, California

SUMMARY

San Diego County is located on the Pacific Ocean at the Mexican border. The 1960 population of approximately 1,000,000 represents a fivefold increase since 1930. The climate is strongly influenced by the Pacific Ocean. As a result, the immediate coast line has a very narrow range of temperature, whereas the inland suburbs experience a much greater range. In general, the climate is characterized by long, dry summers and mild winters with occasional rain.

The County Health Department's main office is in the City of San Diego, and auxiliary field offices are located in several residential communities. Septic tank controls are enforced by the Division of Sanitation of the County Health Department. A percolation test has been used since November 1952 to determine the suitability of soils for use of seepage pits.

Seepage pit construction practices are uniform throughout the County and have been adapted to utilize modern machines. A typical seepage pit is three feet in diameter, lined with a redwood casing, and covered with a concrete slab. Gravel backfill has been required in the annular void around the casing since September 1956.

A total of 164 seepage pits was opened for inspection and comprehensive soils data were obtained at 28 sites. The investigations represent five general soil formations varying greatly in textural and structural characteristics. One soil was classified into coarse and fine textured phases as a result of vertical changes in soil strata. Three methods (a gross performance table, survival curves, and a mathematical model) were employed to describe seepage pit performance.

CONCLUSIONS

The following conclusions apply to the use of seepage pits under the conditions of loading and construction observed in San Diego County, California:

1. A properly designed and constructed seepage pit is an adequate device for the disposal of effluent.

2. Parameters derived from the field data and an average water use of 9760 cubic feet per home per year were used to derive design equations for soil formations. These equations are:

A Soil	
Coarse	$A = 13.5\ t$
Fine	$A = 31.8\ t$
B Soil	$A = 41.8\ t$
C Soil	$A = 25.8\ t$
D Soil	$A = 53.7\ t$
E Soil	$A = 27.3\ t$

   where:

   A is the square feet of pit sidewall area needed per home, and t is the years of expected service.

3. An economic approach showed that minimum costs are obtained with design areas ranging from 243 square feet for the most permeable soil to 537 square feet for the least permeable soil. This approach, assuming a time horizon of 30 years, provides for complete replacement of the seepage pit at 10 to 18 years after the initial installation.

4. The use of gravel backfill in the annular void around the redwood lining improves the structural stability of the redwood lining.

5. Some concrete pipe, when exposed to the gases generated in a septic tank, will decompose and interfere with the successful operation of the septic tank-seepage pit system.

GENERAL INFORMATION

San Diego County, approximately as large as the State of Connecticut, is located in the southwest corner of California on the Pacific Ocean at the Mexican border. Its population of approximately 1,000,000 is concentrated along the coast line of the Pacific Ocean. The City of San Diego with approximately 55 percent of the county population is located on San Diego Bay.

Urban growth since 1940 has been greater proportionately in the County and surrounding suburbs than it has been within the city limits. This growth has necessarily been eastward since the coast line was already heavily developed. At present metropolitan San Diego includes 80 percent of the County population.

Geology.

The geology of the present land formations along the coast can be traced to Tertiary time.* This period was characterized by uplifting and mountain building followed by intermittent submergence with late Tertiary sediments deposited as terraces along the coast. A series of five terraces with approximate elevations of 25, 50, 100, 250, and 500 feet, respectively, have been identified. The two lower terraces are sedimentary coastal deposits of fine sand and silt. The other three terraces are in the San Diego formation which is a lenticular mixture of strata varying in texture and compactness. Some strata, particularly deposits of conglomerate, are more extensive than others; however, the discontinuity of the strata is the most outstanding characteristic of the San Diego formation.

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*A. J. Ellis and C. H. Lee, *Geology and Ground Water of the Western Part of San Diego County, California*, p. 321. U. S. Geological Survey Water Supply Paper 446, 1919.

Soils and Topography.

The soils in the river valleys are mapped in the Yolo series which is a soil without a distinct profile developed on recent alluvial fill. The soil on the coastal terraces is mapped as San Joaquin which is derived from sedimentary deposits in San Diego County. The San Joaquin soil profile is characterized by a red to reddish brown colored surface layer, ranging in texture from sandy loam to clay, underlain by heavy clay with distinct columnar structure.

The coastal topography is characterized by relatively level terraces and isolated mesas rising sharply from the interconnected flood plains of the San Diego, Sweetwater, and Otay Rivers. Inland from San Diego, the coastal terraces abut against a low mountain range of primarily granite rock. Surface drainage is excellent throughout the area except for the tidal flats at the river mouths.

Ground Water.

The ground water reservoir in western San Diego County is limited to the alluvial fill in the river valleys. These deposits are usually less than 200 feet deep and the total ground water storage is far less than the yearly water demand. Surface runoff stored in reservoirs and water diverted from the Colorado River network make up the greatest portion of the water supply.

Climate.

San Diego's climate is strongly influenced by the Pacific Ocean. Along the coast line the summer temperatures are lower and the winter temperatures are higher than is typical for this latitude. This pattern changes rapidly as one moves away from the coast, and summer temperatures over 100 degrees are quite common in the eastern suburbs. The growing season averages 365 days in San Diego, and freezing temperatures have occurred only 9 times since 1871. Fifteen miles inland at El Cajon the growing season averages 273 days.

The annual precipitation of 11 inches is concentrated in the winter months with 80 percent falling from November through March. The favorable temperature and rainfall relationship during the long, dry summer season produces a potential evapotranspiration three times as great as the annual precipitation. Weather data which may influence septic tank system performance are summarized in Table 43.

Health Department Organization and Septic Tank Practice.

The San Diego County Health Department is a well-organized City-County unit. Septic tank controls are enforced by the Division of Sanitation which has a staff of approximately 35 professional employees. The main departmental offices are located in San Diego. Auxiliary field offices are located in the north and south County areas.

Septic tank control for San Diego County was initiated in December 1924. This original Ordinance was superceded in December 1941 by Ordinance 234 (new series) which was superceded by Ordinance 1258 (new series) in November 1952. Table 44 summarizes some of the minimum requirements of the 1941 and 1952 Ordinances.

Table 43

Summary of Climatological Data San Diego County, California*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	62	68	55	9.9	3.4	24.9	72
Winter (Dec.Jan.Feb.)	56	64	48	5.8	1.7	14.6	79
Summer (Jun.Jul.Aug.)	67	72	62	0.2	0.0	1.0	66

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1949-58	63	57	69	9.1	5.5	0.2
1954-58	64	58	70	8.8	5.7	0.1
Sept.'57-Aug.'58	65	61	70	14.0	5.2	0.0

*Weather Bureau Station at Municipal Airport, San Diego, California.

Table 44

Minimum Requirements for Septic Tank Systems
San Diego County, California

Period	Minimum Lot Size (Ft^2)	Septic Tank Capacity (Gals.)	Absorption Area Pit Sidewall (Ft^2)
1941-1952	4000	550	Sufficient to provide adequate drainage.
1952-1960	6000	960	Sufficient to provide adequate drainage.*

*Percolation test may be required to determine needed area.

Using experience as a guide, the Division of Sanitation has the County divided into zones of relative suitability for septic tank systems. These zones are used as general guides to determine the amount of absorption area needed. Percolation tests are required to determine the needed area in all zones where it is questionable that the minimum area will be adequate.

The seepage pit percolation test was initiated in November 1952, and required that a minimum of 1000 gallons of water seep out of a full-scale seepage pit within 24 hours after it is filled. The test was revised in August 1957 to require that a minimum of 1500 gallons of water seep out within 24 hours after the pit is filled. The tests must be conducted or supervised by a qualified engineer.

RESULTS OF FIELD STUDIES

Field studies were conducted in San Diego County at three different times. A two-week preliminary survey was conducted in October 1957. Further studies were conducted from January through April and August through November 1958. Table 45 summarizes the studies completed in San Diego County, California.

Table 45

Summary of Field Activities
San Diego County, California

Survey Unit	General Surveys	Detailed Studies	Total
A Soil			
Coarse	22	5	27
Fine	13	3	16
B Soil	43	6	49
C Soil	30	6	36
D Soil	20	2	22
E Soil	8	2	10
Miscellaneous	-	4	4
Total	136	28	164

Subdivision and Soil Descriptions.

Subdivision tracts in the study area were relatively small, and the general survey units include several subdivision tracts. In general, the homes in these subdivisions are moderately priced, five- and six-room ranches. Lot sizes range from 6,000 to 15,000 square feet, and yard development ranges from none to well-landscaped lots with frequent shrubbery plantings. Table 46 gives the location and a description of the homes in each of the general survey units.

Five soil formations were delineated using information from local sources and data collected from field investigations. Brief descriptions of these soil formations are also given in Table 46. A minimum of two detailed studies was conducted in each soil formation to gather comprehensive soils data. Additional detailed studies were conducted as needed to obtain a more complete knowledge of the soil boundaries and variability. Data collected at these detailed study sites are summarized in Table 47.

Rapid vertical changes in texture necessitated a subdivision of A Soil. The 8 detailed investigations disclosed a relatively uniform stratum of gravelly coarse sand at about 10 feet below the ground surface. Pits drilled through this stratum penetrated into much finer textured strata. The general survey cases were separated into two groups: one with all ponding in the finer strata, and the other with ponding in either the coarse stratum or both coarse and fine strata.

Table 46

Descriptions of General Survey Units and Soil Formations San Diego County, California

Survey Unit and Location	Home and Yard Description	Soil Description
A (Bonita Mesa) Located about 2 miles east of Chula Vista on Bonita Mesa Rd.	5 & 6 rooms, 3 bedrooms, 2 baths, attached carports, concrete drives, most have food waste grinders & automatic washers. Well-landscaped & well-maintained yards. Average lot size is 12,000 ft^2.	Interbedded strata ranging in texture from gravelly coarse sand to very fine sandy loam, a continuous gravelly coarse sand stratum is encountered at about 12 ft.
B (South Chula Vista) Between 3rd & 5th Aves. from Emerson St. to Moss St.	5 & 6 rooms, 2 & 3 bedrooms, 1 & 2 baths, some have food waste grinders, most have automatic washers. Generally well-maintained lawns with few decorative plantings. Lot size is 6-10,000 ft^2.	A heterogeneous profile with interbedded strata ranging in texture from coarse sand to clay, sandy clay loam textures predominate.
C (South Chula Vista) Between 4th & 5th Aves. from Emerson St. to Orange Ave.	4-6 rooms, 2 & 3 bedrooms, 1 bath, about half with automatic washers. Yard development ranges from slight to good lawns with occasional decorative plantings. Lot size is 7-10,000 ft^2.	A heterogeneous profile ranging in texture from gravelly coarse sand to clay, coarser textured strata predominate near the bottom of the pits.

Table 46 (Continued)

Survey Unit and Location	Home and Yard Description	Soil Description
D (South Chula Vista) Along 5th Ave. from Moss St. south to Oxford St.	5 & 6 rooms, 3 bedrooms, 1 & 2 baths, attached carports, many have food waste grinders & automatic washers. Yard development is variable with most homes having good lawns. Average lot size is 7,000 ft^2.	A relatively uniform sandy clay to clay deposit with occasional boulders, brackish water encountered at about 55 ft.
E (South Chula Vista) Along 5th Ave. north of Moss St.	4-6 rooms, 2 & 3 bedrooms, 1 bath, about half with automatic washers. Yard development is variable with most homes having good lawns. Average lot size is 7,000 ft^2.	Similar to Unit D except for a medium sand stratum at about 30 ft. and a coarse sand stratum at about 50 ft.

Table 47

Detailed Soil Investigation Results
San Diego County, California

General Survey Unit	Number of Tests	Percolation Rate*		Slope Factor**		Visual Permeability Rating***	
		Mean	Range	Mean	Range	Mean	Range
A Soil							
Coarse	5	.348	.063-1.38	.294	.008-1.02	1.8	1.5-2.2
Fine	3	.014	.003-.007	.008	.002-.019	2.8	2.7-3.0
B Soil	6	.011	.001-.033	.002	.0003-.005	3.6	3.1-3.7
C Soil	6	.177	.015-.856	.026	.004-.070	3.4	2.8-3.6
D Soil	2	.012	.005-.019	.002	.002-.003	3.6	3.5-3.8
E Soil	2	.026	.008-.044	.004	.003-.006	3.3	-

*Rate in gal./min./ft^2 at a head equal to the depth of ponding in the existing seepage pit for the slowest percolation test recession rate curve.

**A plot of $\frac{1}{H}$ (head in ft.) vs. Σt (hrs.) for the percolation test produces a straight line with slope m. The slope factor equals $m\frac{D}{4}$ where D equals the pit diameter.

***Average value weighted for thickness of strata and based on a scale where: 1 = excellent, 2 = good, 3 = fair, and 4 = poor.

Construction and Loading.

Construction and loading factors which may affect the operation of seepage pits are given in Table 48. All pits were three feet in diameter and lined with octagonal redwood casing. Use of gravel backfill in the annular void around the lining was optional during installation of the seepage pits inspected. The presence or absence of this backfill and the condition of the lining were determined for 136 general survey cases. The results, presented in Table 49, show that fewer linings have collapsed when the annular void is filled with gravel. Variation in construction techniques, which may also influence the structural stability of the redwood lining, are not evaluated by these results.

Interesting observations concerning the durability of concrete pipe were also made during the general surveys. A total of 16 seepage pit systems with concrete connecting lines was opened for inspection. All lines inspected had some decomposition, and three lines were so badly decomposed that they needed replacement. These observations indicate the desirability of having a high quality concrete pipe for use in septic tank systems.

Septic tanks were not opened during the general survey. General knowledge of construction practice indicates that all tanks were rectangular in shape with two or three compartments. A few tanks, particularly those at older homes, could have liquid capacities of 500 to 750 gallons. In general, the tanks have two compartments and a liquid capacity of 1000 gallons.

Loading data are relatively uniform for the six survey units. Person load ranges from a low of 3.6 in C Soil to 4.2 in A Soil, while water use ranges from a low of 9,200 to 13,500 cubic feet per year in the same survey units, respectively. Water use was based on the winter months to avoid the effect of summer irrigation.

Table 48

Construction and Loading Data
San Diego County, California

Item		A Soil Coarse	A Soil Fine	B Soil	C Soil	D Soil	E Soil
Number of Observations		27	16	49	36	22	10
System Age, Yrs.							
	Median	3.7	3.4	4.0	7.6	3.7	8.6
	Range	2.5-9.9	.8-6.9	1.0-9.0	2.5-11.6	1.3-9.6	2.6-17.2
Person Load, No.							
	Median	4.2	4.0	4.0	3.6	4.0	3.9
	Range	2-7	2-7	2-8	2-6	2-7	2-6
Water Use, $Ft^3/Yr. \times 10^{-3}$ (Nov.Dec.Jan.Feb.)							
	Median	13.5	10.4	11.0	9.2	11.6	10.6
	Range	7.2-20.5	3.1-20.8	3.9-30.8	4.7-15.6	6.3-18.1	4.8-19.7
Pit Diameter, Ft.							
	Median Range	All 3.0	All 3.0	All 3.0	All 3.0	All 3.0	All 3.0
Pit Depth, Ft.							
	Median	23	36	40	35	58	57
	Range	17-31	31-51	20-69	20-54	52-64	36-59
Pit Sidewall Area, Ft^2							
	Median	174	298	395	298	503	493
	Range	132-256	255-443	187-610	172-464	461-552	319-523

Table 49

Effect of Gravel Backfill in Annular Void on Structural Stability of Redwood Linings San Diego County, California

Type of Systems	No. of Obs.	Lining Satisfactory	Lining Collapsed	Percent Collapsed
Pits with gravel backfill in annular void.	76	75	1	1.3
Pits without gravel backfill in annular void.	60	49	11	18.4

Many modern household appliances may influence the loading of septic tank systems. Data on several of these appliances are summarized in Table 50. The percentage of homes with food waste grinders and water softeners is relatively high while very few homes have dishwashers. It should be noted that regeneration wastes from the water softeners are seldom discharged to the system. Virtually all homes are equipped with clothes washers, but the relative percentage of manual and automatic sequence units varies greatly. In contrast to practice in Maricopa County, Arizona, nearly all clothes washers are discharged to the septic tank system.

Gross Performance.

Three classes of performance - failed, surcharged, or ponded - were established and defined. A system with a history of sluggish plumbing fixtures or surface seepage of effluent was classified as failed. Further investigation was conducted when sluggish fixtures were reported to determine that unsatis-

Table 50

Household Appliances
San Diego County, California

Appliance	Percentage of Homes with Appliance A Soil Coarse	A Soil Fine	B Soil	C Soil	D Soil	E Soil
Food Waste Grinder	82	50	31	6	73	10
Dishwasher	4	0	2	0	0	0
Water Softener	41	44	53	44	44	60
Clothes Washer	100	100	100	98	95	100
Manual	4	12	14	36	18	10
Automatic	74	82	63	31	59	10
History of Both	22	6	23	31	18	80

factory seepage pit operation caused the sluggishness. Surcharged and ponded systems were classified by inspection of the seepage pit. The depth of the seepage pit below the bottom of the mortar sealed dome was defined as the useful depth. When the ponded effluent exceeded this depth the system was classified as surcharged; when the ponded effluent did not exceed this depth it was classified as ponded.

Gross performance data for the general survey units are presented in Table 51. Performance is good for all units with only 8 failures recorded for the 160 systems inspected in the general surveys. The limited amount of failure data plus differences in age, loading, and provided soil area prohibit a direct ranking of the soil units by observed performance.

Table 51

Gross Performance
San Diego County, California

Soil Unit	Years of Service Mean	Years of Service Range	Mean Persons (No.)	Mean Sidewall Area (Ft^2)	No. of Obs.	Performance No. Failed	Performance No. Sur-charged	Performance No. Ponded	Percent Failed
A Soil									
Coarse	4.2	2.5-9.0	4.4	180	27	1	0	26	4
Fine	3.4	0.8-6.9	4.2	316	16	0	0	16	0
B Soil	4.9	1.0-9.0	4.2	391	49	2	0	47	4
C Soil	7.6	2.5-11.4	3.6	293	36	4	2	30	11
D Soil	4.8	1.3-7.4	4.1	500	22	1	0	21	4
E Soil	8.9	2.6-17.2	3.8	475	10	0	0	10	0

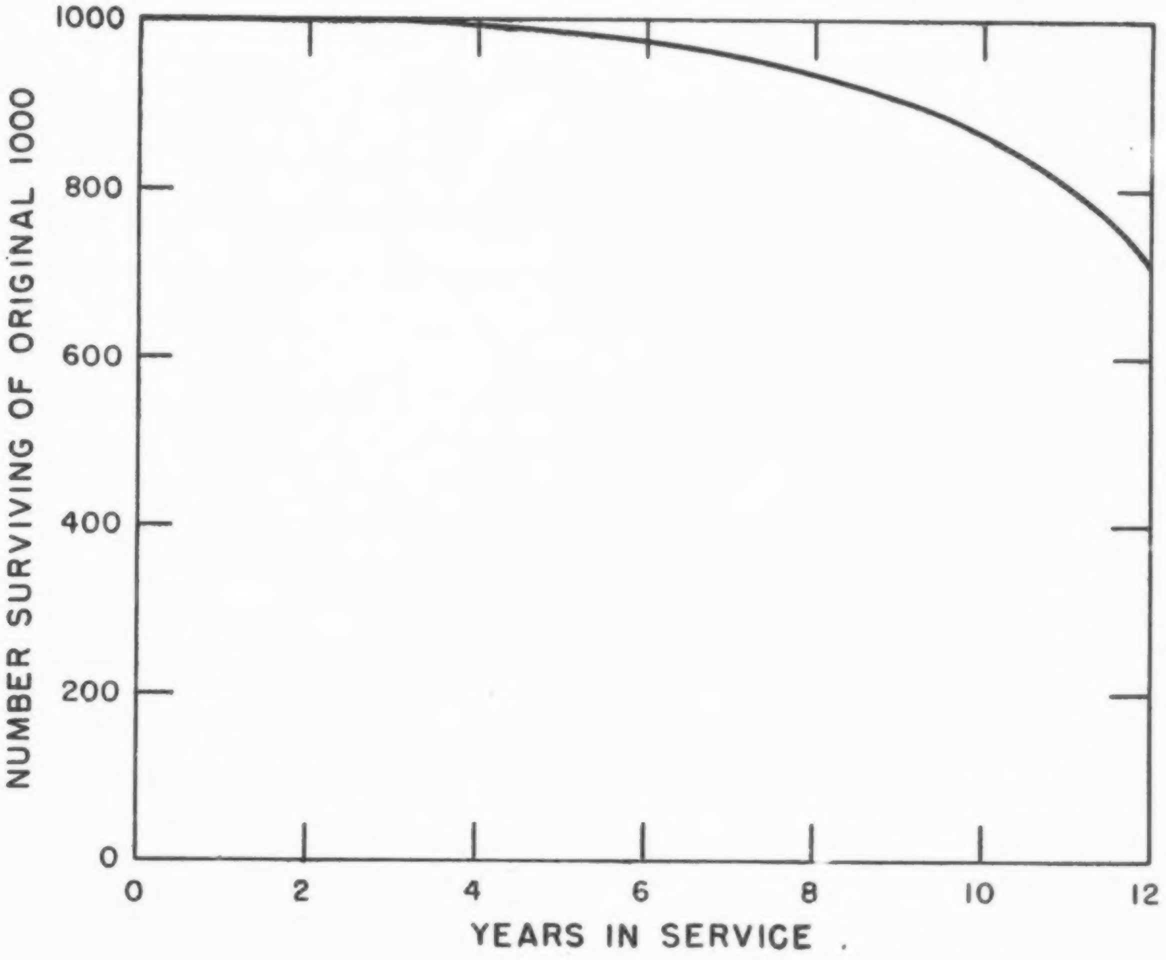
Survival Curves.

Sufficient failure data were not available to draw meaingful survival curves for each general survey unit. The curve presented in Figure 6 is for all systems combined. There is good distribution of the survey cases in the age intervals from 1.0 to 9.9 years as can be seen in the survival curve calculations shown in Table 52. The 80-percent survival age of 11 years is highly satisfactory.

Table 52

Survival Curve Calculations
San Diego County, California

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
All Systems Combined					
0-0.9	159	-	.000	1000	0
1.0-1.9	158	-	.000	1000	0
2.0-2.9	148	-	.000	1000	0
3.0-3.9	134	1	.007	1000	7
4.0-4.9	86	0	.000	993	0
5.0-5.9	71	1	.014	993	14
6.0-6.9	64	1	.016	979	16
7.0-7.9	51	3	.059	963	57
8.0-8.9	25	0	.000	906	0
9.0-9.9	13	1	.077	906	70
10.0-10.9	5	0	.000	836	0
11.0-11.9	4	1	.250	836	209
12.0-12.9	0	0	.000	627	0
13.0-13.9	-	-	-	-	-



SURVIVAL CURVE
SAN DIEGO COUNTY, CALIFORNIA

FIGURE 6

INTERPRETATION OF RESULTS

Data presented in the previous sections provide qualitative evaluations of seepage pit performance. Quantitative evaluation of performance depends on establishment of measurable parameters which represent the interrelationship between load, area, and time. A rational mathematical model* has been developed to express this relationship.

Mathematical Formulation.

The mathematical model expresses the relationship between the soil absorption area, A, required for a given period of operation, t, with a loading factor, Q, as:

$$A = \frac{Q}{kL} + \frac{Q}{L}t \qquad (1)$$

where:

k is the rate reaction constant of interface clogging, and

L is the ultimate interface absorption capacity.

Dividing through by the loading factor, Q, produces equation:

$$\frac{A}{Q} + \frac{1}{kL} + \frac{1}{L}t \qquad (2)$$

which is a linear equation with an intercept of $\frac{1}{kL}$ and a slope of $\frac{1}{L}$. This form of the equation can be used to evaluate the field data.

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*Study of Seepage Beds. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, December 15, 1960.

Evaluation of Field Data.

Parameters were measured in the field which can be substituted for the parameters A, Q, and t in the model equation. They are:

A (ft^2), seepage pit sidewall area wetted by effluent during a known period of service,

I (ft^3/yr.), water consumption which can be used as an estimate of Q, the loading factor, and

t (yrs.), the period of service during which the area, A, was wetted.

These parameters are summarized in Table 54 for each survey unit. The load rate, $\frac{I}{A}$, and the reciprocal load rate, $\frac{A}{I}$, are also given in this Table. Two adjustments were applied to the parameter, I, to improve its accuracy. The climatological data presented in Table 43 show that San Diego has a long, dry summer with high potential evapotranspiration. Excessive irrigation use during this period results in high water use. An adjusted annual use was derived from the metered use for the winter season when irrigation use is at a minimum. A few homeowners diverted clothes washer wastes from the septic tank systems. A correction of 50 gallons per wash load for automatic sequence washers and 25 gallons per wash load for manual sequence washers was deducted from I for these homes. Proportional corrections were made for combinations of automatic and manual sequence washers and for partial discharge of clothes washer wastes to the system.

Food waste grinder, dishwasher, water softener, and house cooler waste discharges are also components of the loading parameter, Q. Scatter diagrams were employed to evaluate the possible effect of these appliances on computed parameters. The over-all variability masked any individual influence which may have been present. Therefore, all homes were included in a single analysis.

Design equations derived from these data are shown in Table 53. The survey units are ranked in decreasing order by the value of the slope factor presented in Table 47. With the exception of E Soil, the design equations fall in increasing order. The slope factor as well as other measured soil parameters for B Soil and D. Soil have similar means.

Table 53

Design Equations and Economic Analyses
San Diego County, California

Survey Unit	Design Equation	Economic Analysis Optimum Renewal Period (Years)	Optimum Design Area (Ft^2)	Present Value of Cost (Dollars)
A Soil Coarse	A = 13.5 t	18	243	322
C Soil	A = 25.8 t	13	335	488
A Soil Fine	A = 31.8 t	12	382	564
E Soil	A = 27.3 t	13	355	507
B Soil	A = 41.8 t	11	460	685
D Soil	A = 53.7 t	10	537	828

Economic Analysis.

A method of analysis* has been developed to determine the most economical soil absorption system to install. The analysis was conducted using cost data collected during the study and a time horizon of 30 years. Results of the analysis are shown in Table 53. Optimum design areas range from a low of 243 square feet for A Soil (Coarse) to a high of 537 square feet for D Soil. There is a clearly evident inverse relationship between the optimum design area and the percolation test parameters shown in Table 47.

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*Harold A. Thomas, James B. Coulter, T. W. Bendixen, and Allan B. Edwards, Technology and Economics of Household Sewage Disposal Systems. Journal Water Pollution Control Federation, February 1960.

Table 54

Water Use Data
San Diego County, California

Soil Type A - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
281	9.0	2.9	132	20,300	154	.007

Soil Type A - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
277	0.8	3.0	68	5,100	75	.013
257	1.5	4.0	61	8,700	143	.007
280	1.8	3.0	92	9,600	104	.010
276	2.2	5.0	105	11,800	113	.009
386	2.2	4.7	141	20,800	148	.007
273	2.5	5.0	108	19,200	178	.006
274	2.6	6.6	111	10,600	96	.010
394	2.7	6.0	75	13,200	176	.006
390	2.9	6.2	77	20,200	262	.004
392	3.1	4.0	9	16,400	1822	.001
387	3.1	6.0	70	21,100	301	.003
388	3.1	4.0	145	16,400	113	.009
269	3.4	4.4	65	15,200	234	.004
255	3.4	3.3	79	10,900	138	.007
256	3.5	4.1	131	15,300	117	.009
268	3.6	4.1	52	12,800	246	.004
266	3.7	3.5	54	8,200	153	.007
260	3.7	3.8	8	12,900	1612	.001
259	3.7	2.0	33	10,700	325	.003
270	3.7	4.6	52	12,300	236	.004
272	3.7	4.0	67	18,800	280	.004
263	3.7	5.0	120	13,500	112	.009
261	3.7	4.1	140	13,000	93	.011

Table 54 (Continued)

Soil Type A - Successful Systems
(Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
258	3.7	4.5	213	12,900	60	.017
265	3.8	4.0	45	13,050	290	.003
264	3.8	3.2	53	11,800	22	.004
275	3.8	7.4	65	20,500	315	.003
271	3.8	4.2	72	15,600	217	.005
262	3.8	4.6	190	16,800	88	.011
393	3.9	3.7	23	7,800	339	.003
286	4.0	5.0	52	16,900	325	.003
285	4.0	2.8	65	16,700	257	.004
267	4.0	3.0	126	18,300	145	.007
278	4.2	6.6	124	10,200	82	.012
395	4.3	4.0	72	17,600	245	.004
391	5.5	2.0	100	3,100	31	.032
279	5.9	2.9	69	8,600	124	.008
282	6.3	2.0	15	7,400	493	.002
389	6.9	4.6	135	5,800	43	.023
284	7.1	5.0	139	11,700	84	.012
396	7.5	7.0	148	7,200	49	.021
283	7.7	3.0	79	10,000	127	.008

Soil Type B - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
403	5.0	4.0	541	30,800	57	.018
304	6.8	8.3	154	9,800	62	.016

Table 54 (Continued)

Soil Type B - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
323	1.0	4.0	104	15,000	144	.007
322	1.9	5.0	213	13,800	65	.015
321	1.9	6.0	102	9,200	90	.011
320	2.1	4.0	181	10,800	60	.017
319	2.3	3.2	136	12,400	91	.011
318	2.3	4.0	170	12,600	74	.013
324	2.3	7.0	183	9,300	51	.020
317	2.5	3.9	248	16,500	67	.015
290	3.2	3.0	85	8,100	95	.010
400	3.3	4.0	199	10,000	50	.020
401	3.4	4.1	190	11,500	61	.017
398	3.4	4.0	297	13,600	45	.022
295	3.5	5.0	227	10,300	45	.022
399	3.5	4.5	238	11,100	49	.021
294	3.7	3.2	169	13,700	81	.012
309	3.7	4.7	200	15,100	76	.013
291	3.7	4.0	149	8,500	57	.018
326	3.8	5.8	172	11,000	64	.016
307	3.8	4.8	197	12,400	63	.016
289	3.8	3.8	86	10,600	123	.008
308	3.9	4.2	248	11,600	47	.021
299	3.9	6.0	140	13,700	98	.010
288	3.9	4.4	141	7,500	53	.019
297	3.9	4.0	248	13,300	54	.019
293	4.0	4.4	170	8,000	47	.021
296	4.0	5.4	264	12,900	49	.020
292	4.0	4.8	357	14,000	39	.026
287	4.0	5.0	111	7,300	66	.015

Table 54 (Continued)

Soil Type B - Successful Systems
(Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
300	4.0	5.0	217	15,200	70	.014
298	4.0	5.3	254	10,900	43	.023
397	4.0	3.9	330	13,300	40	.025
311	4.5	3.7	240	16,400	68	.015
325	5.3	4.0	81	10,300	127	.008
314	6.0	3.0	202	10,300	51	.020
303	6.3	3.3	174	9,400	54	.019
302	6.3	4.8	346	12,200	35	.028
305	6.5	2.9	129	12,700	99	.010
313	6.5	2.0	161	11,500	71	.014
402	6.7	3.1	321	9,100	28	.035
328	7.0	4.0	360	5,900	16	.061
301	7.1	4.0	213	8,100	28	.026
316	7.2	2.1	187	13,000	70	.014
315	7.2	1.7	90	8,900	99	.010
310	7.5	3.4	165	3,900	24	.042
306	8.6	3.6	251	8,800	35	.029
312	8.7	4.0	290	7,300	25	.040
327	9.0	2.0	297	8,700	29	.034

Soil Type C - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
357	4.2	4.0	172	12,600	73	.014
349	7.3	5.6	208	10,700	51	.019
334	7.8	3.3	223	10,000	45	.022
408	11.6	6.2	278	15,600	56	.018

Table 54 (Continued)

Soil Type C - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
333	2.5	2.0	14	4,700	335	.003
340	4.4	2.0	57	8,600	151	.007
330	5.6	4.0	222	5,700	26	.039
350	5.8	5.3	250	13,500	55	.018
336	6.5	4.0	61	8,900	146	.007
335	6.6	2.8	232	7,000	30	.033
332	6.8	4.1	122	9,400	77	.013
337	6.8	4.7	280	11,100	40	.025
329	7.0	3.0	81	7,300	90	.011
409	7.0	3.9	160	-	-	-
345	7.2	2.9	87	6,600	76	.013
410	7.2	3.7	192	-	-	-
353	7.3	4.6	228	12,300	54	.019
343	7.3	3.8	249	9,500	38	.026
347	7.4	1.8	127	5,800	45	.022
346	7.4	4.0	256	12,300	48	.021
348	7.5	2.6	95	6,100	64	.016
406	7.5	2.7	307	10,700	35	.029
342	7.6	2.0	94	7,400	79	.013
344	7.7	3.0	194	9,200	47	.021
352	7.8	2.5	143	11,500	80	.012
356	7.8	4.8	276	10,900	39	.025
331	8.1	3.8	179	8,900	50	.020
338	8.7	3.5	129	7,100	55	.018
405	8.8	5.2	190	11,000	58	.017
341	8.8	3.5	288	8,200	28	.035
339	8.9	2.7	245	7,000	29	.035
404	9.0	3.7	192	11,400	59	.017
355	9.1	3.9	141	9,100	65	.015
354	9.8	3.4	290	9,100	31	.032
407	10.6	3.0	206	11,700	56	.018
351	11.4	4.0	228	7,300	32	.031

Table 54 (Continued)

Soil Type D - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
366	7.4	7.0	528	18,100	34	.029

Soil Type D - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
369	1.3	4.3	108	7,800	72	.014
368	1.6	5.0	206	-	-	-
374	1.8	3.2	188	10,500	56	.018
372	1.8	5.5	285	15,300	54	.019
377	1.9	4.8	140	13,400	96	.010
373	2.0	5.0	244	17,300	71	.014
370	3.0	3.0	229	-	-	-
364	3.5	4.0	239	13,400	56	.018
359	3.6	4.0	231	8,000	35	.029
413	3.6	3.9	254	10,800	43	.024
361	3.6	5.9	293	15,100	52	.019
371	3.6	2.0	181	7,700	43	.024
358	3.7	3.5	195	8,700	45	.022
362	3.7	4.3	256	17,500	68	.015
360	3.7	5.3	302	15,300	51	.020
365	3.8	6.2	451	11,200	25	.040
363	4.0	2.1	191	10,300	54	.019
367	8.2	3.7	257	6,300	25	.041
376	8.5	2.0	254	11,800	46	.022
411	8.8	3.9	480	10,500	22	.046
375	9.1	2.3	253	6,300	25	.040

Table 54 (Continued)

Soil Type E - All Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
382	2.6	4.2	142	19,700	139	.007
381	5.2	4.1	231	10,800	47	.021
385	7.2	1.5	61	4,800	79	.013
378	7.3	3.7	342	10,400	30	.033
383	7.9	6.1	356	14,800	42	.024
384	9.2	2.7	192	10,800	56	.018
379	9.4	5.2	386	14,200	37	.027
414	11.5	3.8	251	9,900	39	.025
380	11.8	2.7	183	5,100	28	.036
415	17.2	2.6	315	6,800	22	.046

*Derived from average winter (November, December, January, and February) use.

SECTION VII

MARICOPA COUNTY,
ARIZONA

Maricopa County, Arizona

SUMMARY

Maricopa County, the home of the state capital, Phoenix, is located in south central Arizona. The population of the County increased sevenfold from 1910 to 1960. Metropolitan Phoenix has accounted for most of this population explosion. The County has an arid, desert climate characterized by long, hot summers and short, mild winters. The annual rainfall of 7.6 inches occurs as summer thundershowers and low intensity winter storms.

The Maricopa County Health Department is a well-organized unit and septic tank controls are enforced by the Division of Environmental Health. County regulations since August 1957 include a percolation test for determining seepage pit absorption area requirements.

Septic tank design and construction practice have been adapted to take full advantage of mechanized equipment; however, there is considerable variability in these factors from site to site. Deep, small diameter, unlined seepage pits are commonly installed in stable soil formations; while shallow, large diameter, lined seepage pits are installed in unstable soil formations. The pits are covered with a brick dome and multiple pit installations have distribution boxes.

A total of 269 septic tank-seepage pit systems in 4 general soil formations was opened for inspection. Comprehensive soils data were obtained at 32 of these sites to delineate soil boundaries and identify the soil characteristics. One soil formation was classified according to deep and shallow phases. Three methods (a gross performance table, survival curves, and a mathematical model) were used to evaluate seepage pit performance.

CONCLUSIONS

The following conclusions apply to the use of seepage pits under the conditions of loading and construction observed in Maricopa County, Arizona.

1. The seepage pit, when properly constructed, provides a suitable method for disposal of effluent.

2. Parameters derived from field data and an average water use of 9760 cubic feet per year were used to derive general design equations for 4 soil formations. These equations identified by subdivision are as follows:

Belden Courts, Campo Bello, and Griffith Park	$A = 50.4\ t$
East Broadway Additions	
Septic Tanks	$A = 18.2\ t$
Cesspools	$A = 38.4\ t$
Maryvale Parks	
Shallow Soil	$A = 22.0\ t$
Deep Soil	$A = 37.4\ t$
Squaw Peak Heights and McLellan Manor	$A = 30.9\ t$

3. An economic approach assuming a time horizon of 30 years shows that minimum costs are obtained with design areas ranging from 291 square feet to 534 square feet. These optimum design areas result in complete replacement of the seepage pit at 11 to 16 years following the initial installation.

4. Data collected in one subdivision indicate the septic tank-seepage pit system makes more efficient use of the soil than cesspools for disposal of household sewage.

GENERAL INFORMATION

Maricopa County, occupying 9226 square miles in the south central part of Arizona, was formed from a part of Yavapai County in 1871. The state capital, Phoenix, is located in the Salt River valley on U. S. Highway 80. Both the County and the City are relatively young, and the greatest development of the area has occurred within the last 40 years. Population in the County has mushroomed from 90,000 in 1910 to 664,000 in 1960. This growth is concentrated in Phoenix and the surrounding residential communities which make up metropolitan Phoenix.

Geology.

The area around Phoenix is characterized by broad, gently sloping, connecting valleys dotted with numerous small hills and mountains.* These hills and mountains are probably the peaks of small mountain ranges which have been nearly buried by extensive alluvial deposits. These alluvial deposits, primarily from the Pleistocene epoch, are extremely variable, ranging from a few inches to many hundreds of feet in thickness.

Extreme heterogeneity (both horizontally and vertically) in the alluvial deposits is caused by fluctuating intensities and volumes of flow in the transporting streams. Soil texture at the same relative depth may vary from clay to gravel and boulders over a very short distance.

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*H. R. McDonald, H. N. Wolcott, and J. D. Hem, Geology and Ground Water Resources of the Salt River Valley Area, Maricopa and Pinal Counties, Arizona. U. S. Geological Survey, February 4, 1947.

Strata of caliche (a highly calcareous rock-like material) exist throughout most of the valley deposits. These strata are characteristically impermeable and they interfere with the downward percolation of water. The degree of consolidation and cementation of other deposits is also of extreme importance when considering the permeability of the various formations. Sands and gravels along the stream channels and flood plains are unconsolidated and highly permeable, yet some formations are tightly compacted and relatively impermeable.

Soils and Topography.

The soils of Maricopa County are of the Red Desert group. These soils are commonly referred to as soils with young, immature profiles because they are developed in a climate with very little precipitation. There is very little differentiation in the mechanical composition of the different horizons, and there is widespread distribution of saline soils. The general topography of the area is dominated by smooth-surfaced alluvial fans with gentle slopes, but the fans are rough and rolling with evidence of severe erosion at the bases of the mountain ranges.

Regional drainage as a whole is excellent. The valley is interlaced with a network of shallow, branching arroyos. Many of these have been obliterated by cultivation and land development. The resulting runoff during high intensity rains is diverted into aritificial drainage channels or allowed to flood some of the lower areas.

Ground Water.

The alluvial deposits of the Salt River valley form a large natural ground water reservoir. Until 1920 recharge to the reservoir exceeded depletion, and there was a continuous rise in the mean water table. This trend was reversed by increased usage for irrigation.

Climate.

Phoenix is in an arid desert climate characterized by long, hot summers and short, mild winters. Low relative humidity, low rainfall, and a high percentage of sunshine combine to give the area an extremely high potential evapotranspiration. Table 55 gives a summary of climatological factors which may influence the operation of septic tank systems. The annual rainfall of 7.6 inches is distributed throughout the year. The summer and fall rainfall occurs as thundershowers of high intensity confined to relatively small areas, while the winter and spring storms are more prolonged, low intensity storms encompassing large areas.

Health Department Organization and Septic Tank Practice.

The Maricopa County Health Department is a well-organized unit supervising many phases of public health. The septic tank program is under the jurisdiction of the Division of Environmental Health. In 1958 the septic tank program required three general sanitarians, one clerk, and supporting administrative personnel. The cost of the septic tank program for fiscal year 1957-1958 was $32,000. During this period approximately 5800 new septic tank systems were installed, making the average control cost $5.50 per system.

Table 55

Summary of Climatological Data
Maricopa County, Arizona*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	70	85	56	7.6	2.8	19.7	93
Winter (Dec.Jan.Feb.)	53	67	40	2.4	0.1	6.9	94
Summer (Jun.Jul.Aug.)	88	102	74	2.1	0.2	8.2	95

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1949-58	71	54	88	7.0	1.8	2.4
1954-58	71	55	88	6.5	1.7	2.4
Jun.'57-May '58	71	55	90	8.9	1.4	1.8

*Weather Bureau Station at Sky Harbor Airport, Phoenix, Arizona.

Prior to January 1955 inspection of septic tank installations in Maricopa County was performed by the Arizona State Department of Health. At this time the Maricopa County Health Department assumed full responsibility for septic tank system control. Lacking strong State and County regulations, they relied on the existing Federal Housing Administration minimum property requirements until they formulated comprehensive County regulations in August 1957. A revised sanitary code became effective in April 1959. Table 56 shows a chronological summary of the minimum septic tank system requirements which have been used in Maricopa County.

County regulations since August 1957 include a percolation test for determining seepage pit absorption areas. The test is conducted in a full-scale seepage pit under the supervision of Health Department personnel. To be accepted a pit must be capable of absorbing 3 times the liquid capacity of the septic tank in a period of 12 hours.

Table 56

Minimum Requirements for Septic Tank Systems
Maricopa County, Arizona

Period	Septic Tank Capacity (Gals.)	Absorption Area of Pit Sidewall (Ft^2)
Prior to 1945	300	No regulation.
1945-1952	500	Four lineal feet of porous strata.
1952-1957	500*	Four lineal feet of porous strata.
1957-1959	600	100 ft^2

*Increase 50 percent for addition of a food waste grinder.

RESULTS OF FIELD STUDIES

Studies were conducted in Maricopa County from January 1958 through July 1958 and for a two-week period in November 1958. Examinations were conducted in seven subdivisions representing many soil formations. The subdivisions were selected for availability of accurate loading and construction information and uniformity of soil. Table 57 summarizes the studies completed in each subdivision.

Table 57

Summary of Field Activities
Maricopa County, Arizona

Subdivision	General Survey	Detailed Studies	Total
Belden Courts	56	2	58
Campo Bello	20	2	22
Griffith Park	16	2	18
East Broadway Additions			
Septic Tanks	34	3	37
Cesspools	21	0	21
Maryvale Parks	51	7	58
Squaw Peak Heights	28	3	31
McLellan Manor	11	2	13
Miscellaneous	0	11	11
Total	237	32	269

Subdivision and Soil Descriptions.

The seven subdivisions selected for general surveys comprise a representative sample of suburban development in Maricopa County. The homes are of ranch style construction with values ranging from approximately $8,000 to $20,000 at the time of the survey; lot sizes ranged from 6,300 to 36,900 square feet; and yard development ranges from none to extensive plantings of shrubbery and trees. Table 58 gives the location and description of each subdivision. A brief description of the general soil conditions in each subdivision is also included in this Table.

Comprehensive soil investigations were conducted at two or more sites in each subdivision. These investigations were made to delineate the soil formation boundaries and measure soil parameters which could be used as possible guides for soil system design requirements. Data from the soil investigations are summarized in Table 59.

The Maryvale Parks subdivision has been further classified into deep and shallow phases. A very permeable sand stratum was encountered at 10 to 20 feet. Pits terminating in this stratum were classified as shallow; those penetrating beyond this stratum into finer textured strata were classified as deep.

Belden Courts, Campo Bello, and Griffith Park subdivisions have soil formations with similar permeability characteristics; therefore, data for these subdivisions were combined for further analysis.

Table 58

Description of Subdivisions and Soil Formations
Maricopa County, Arizona

Subdivision and Location	Home and Yard Description	Soil Description
Belden Courts east at 40th St. & Van Buren.	4 rooms, 2 bedrooms, 1 bath. Yard development varies from no lawn & few shrubs to well-maintained, extensively landscaped lots. Paved streets. Average lot size is 6,800 ft^2.	Clay to clay loam soil underlain by a compact gravelly loam formation with lenticular strata of coarser texture.
Campo Bello 15 miles northeast at Bell Rd. & 32nd St.	4 rooms, 2 bedrooms, 1 bath. Yard development is minimum. Semirural area with large lots. Gravel streets. Average lot is 36,900 ft^2.	Clay loam soil underlain by variable strata ranging from sandy loam to silty clay in texture. Much of the underlying formation is caliche, a highly calcareous rock-like material.
Griffith Park east at 44th St. & McDowell near Belden Courts.	5 & 6 rooms, 3 bedrooms, 1½ baths, attached carports. Well-established & well-maintained lawns, frequent shrubbery & citrus plantings. Paved streets, sidewalks, & drives. Average lot size is 6,300 ft^2.	Similar to Belden Courts; however, the formation is somewhat finer textured and a water table was encountered at 24-26 ft.
East Broadway Additions southeast at 20th St. & Broadway.	Homes varying in size, averaging 4 rooms, 2 bedrooms, 1 bath. Yard development & maintenance is variable. Paved streets. Average lot is 7,000 ft^2.	Recent river terrace deposits characterized by silt and clay strata overlying coarse sand and gravel. Depth to coarse deposits is variable.

Table 58 (Continued)

Subdivision and Location	Home and Yard Description	Soil Description
Maryvale Parks northwest at 27th Ave. & Bethany Home Rd.	5 & 6 rooms, 3 bedrooms, 1 bath. Well-established & landscaped lawns. Paved streets & drives. Average lot is 6,500 ft^2.	Silt loam to clay loam underlain by interbedded alluvial strata ranging from coarse sand and gravel to clay loam in texture with the coarser strata occurring at 10-20 ft.
McLellan Manor northeast at 12th St. and Ocotillo Rd.	5-7 rooms, 3 bedrooms, $1\frac{1}{2}$ baths, attached carports. Many with food waste grinders & dishwashers. Extensively landscaped, well-maintained lots. Paved streets, sidewalks, & drives. Average lot size is 8,900 ft^2.	Loam to stony loam soil underlain by interbedded strata of variable composition ranging from gravelly loam to silty clay loam with lenticular fine gravel strata. Gravel is sharp and angular.
Squaw Peak Heights northeast at 12th St. and Glendale Rd. near McLellan Manor.	5-7 rooms, 3 bedrooms, $1\frac{1}{2}$ baths, attached carports. Several have food waste grinders & refrigerated air conditioning. Extensively landscaped lots with frequent citrus plantings. Paved streets & drives. Average lot is 10,400 ft^2.	Same as McLellan Manor.

Table 59

Detailed Soil Investigation Results
Maricopa County, Arizona

Location of Soil Formation	Number of Tests	Percolation Rate*		Slope Factor**		Visual Permeability Rating***	
		Mean	Range	Mean	Range	Mean	Range
Belden Courts, Campo Bello, and Griffith Park	6	.084	.035-.124	.020	.007-.028	3.3	2.9-3.7
East Broadway Add.	[illegible]	.254	.050-.494	.425	.102-.846	1.4	1.0-1.9
Maryvale Parks							
Shallow Soil	2	.310	.053-.567	.207	.094-.320	2.2	2.2-2.2
Deep Soil	5	.109	.015-.183	.029	.012-.056	2.8	2.6-3.4
Squaw Peak Heights and McLellan Manor	5	.175	.076-.309	.085	.041-.124	2.5	2.3-2.7

*Rate in gal./min./ft^2 at a head equal to the depth of ponding in the existing seepage pit for the slowest percolation test recession rate curve.

**A plot of $\frac{1}{H}$ (head in ft.) vs. Σt (hrs.) for the percolation test produces a straight line with slope m. The slope factor equals $m \frac{D}{4}$ where D equals the pit diameter.

***Average value weighted for thickness of strata and based on a scale where: 1 = excellent, 2 = good, 3 = fair, and 4 = poor.

Construction and Loading.

Construction and loading factors which may affect the performance of seepage pits are presented in Table 60. There are large variations between subdivisions in both construction and loading features. Deep, small diameter, unlined seepage pits were installed in the less permeable soils while shallow, large diameter, lined seepage pits were installed in the more permeable soils. Lined seepage pits were installed in East Broadway Additions, Maryvale Parks (Shallow Soil), and McLellan Manor.

In Griffith Park a distribution box was used to connect two pits in parallel. Total area for these systems was taken as the sum of the areas of the individual pits.

Septic tank systems and cesspool systems were both used in East Broadway Additions. The 58 general surveys included 21 homes with cesspools. Pit construction methods and area provided were similar for both systems.

Water use was based on the consumption during the winter months. This was done to avoid the extremely variable and excessively high consumption caused by lawn watering and use of evaporative-type house coolers during the summer months. The effect of these factors on water use has been covered extensively in a previous report.*

The range in person load is similar for all subdivisions, and the medians are relatively close to the national average of 3.7 persons per home. The range in system age is a result of sample selection since a wide range in this factor is desirable for the analysis of data.

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*Domestic Water Use in Phoenix, Arizona. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, June 15, 1959.

Table 60

Construction and Loading Data
Maricopa County, Arizona

Item	Belden Courts, Campo Bello, & Griffith Park	East Broadway Additions		Maryvale Parks		Squaw Peak Heights & McLellan Manor
		Septic Tanks	Cesspools	Shallow Soil	Deep Soil	
Number of Observations	98	37	21	35	23	44
System Age, Yrs.						
Median	5.4	3.8	3.4	4.2	5.8	5.1
Range	0.2-6.6	0.9-11.0	1.8-11.4	3.8-6.0	1.4-6.2	3.0-6.5
Person Load, No.						
Median	3.3	3.0	3.0	4.0	3.6	3.4
Range	1.7-7.0	1.7-8.8	2.0-7.1	1.7-6.0	2.0-6.0	1.3-6.0
Water Use, $Ft^3/Yr. \times 10^{-3}$ (Dec.Jan.Feb.)						
Median	9.2	10.6	7.1	9.1	10.1	9.2
Range	4.3-19.2	3.8-26.1	3.5-13.7	5.4-15.4	6.0-17.3	4.6-26.2
Septic Tank Cap., Gals.						
Median	500	550	None	550	500	500
Range	500-750	500-810		500-750	500-750	500-1000
Pit Diameter, Ft.						
Median	2.6	3.7	3.7	4.0	2.7	3.0
Range	2.1-3.7	2.4-5.1	2.1-4.3	2.7-4.5	2.5-3.9	2.6-4.6
Pit Depth, Ft.						
Median	29	10	8	16	26	22
Range	11-38	7-14	7-15	14-18	20-33	10-32
Pit Sidewall Area, Ft^2						
Median	219	79	82	151	183	162
Range	98-418	43-163	57-156	87-186	149-350	76-412

Data on household appliances which may influence septic tank system loading are shown in Table 61. Squaw Peak Heights and McLellan Manor were the only subdivisions where relatively high percentages of the homes were equipped with a food waste grinder, dishwasher, or water softener. Nearly all homes were equipped with a clothes washer, but the relative percentage of manual or automatic sequence machines is variable. The waste from many of the clothes washers is not discharged to the septic tank system. It should also be noted that the majority of the water softeners are commercially serviced and do not discharge regeneration wastes to the septic tank system.

Gross Performance.

Three classes of performance - failed, surcharged, or ponded - were established and defined. A system with a history of sluggish plumbing fixtures or surface seepage of effluent was classified as failed. Further investigation was conducted when sluggish fixtures were reported in order to determine whether unsatisfactory seepage pit operation caused the sluggishness. Surcharged and ponded systems were classified by inspection of the seepage pit. The depth of the seepage pit below the bottom of the mortar sealed dome was defined as the useful depth. When the ponded effluent exceeded this depth, the system was classified as surcharged; when the ponded effluent did not exceed this depth, it was classified as ponded.

Gross performance data are presented in Table 62. Qualitative differences between the subdivisions are clearly evident. For example, performance of septic tank systems in East Broadway Additions and Maryvale Parks (Deep Soil) is virtually identical but twice as much soil area was provided for Maryvale

Table 61

Household Appliances
Maricopa County, Arizona

Appliance	Percentage of Homes with Appliance					
	Belden Courts, Campo Bello, & Griffith Park	East Broadway Add.		Maryvale Parks		Squaw Peak Heights and McLellan Manor
		Septic Tank	Cesspools	Shallow Soil	Deep Soil	
Food Waste Grinder	4	14	5	3	4	30
Dishwasher	0	0	0	3	9	23
Water Softener	5	16	5	9	9	50
Clothes Washer	92	92	91	95	91	84
Manual	39	46	86	11	9	7
Automatic	42	35	5	55	65	70
History of Both	11	11	0	29	17	7

Table 62

Gross Performance
Maricopa County, Arizona

Subdivision	Years of Service		Mean Persons	Mean Sidewall	No of	Performance			
	Mean	Range	(No.)	Area (Ft^2)	Obs.	No. Failed	No. Sur-charged	No. Ponded	Percent Failed
Belden Courts, Campo Bello, & Griffith Park	4.3	0.4-6.6	3.3	224	98	21	18	59	21
East Broadway Add.									
Septic Tanks	5.5	0.9-11.0	3.7	87	37	15	9	13	41
Cesspools	4.1	1.8-11.4	3.7	92	21	9	4	8	43
Maryvale Parks									
Shallow Soil	4.2	1.8-6.0	4.0	150	35	2	2	31	6
Deep Soil	5.4	1.4-6.2	3.6	183	23	10	2	11	43
Squaw Peak Heights & McLellan Manor	4.8	3.0-6.2	3.4	170	44	13	7	24	30

Parks (Deep Soil). A ranking of the subdivisions according to performance would be misleading because of the differences in mean system age and sidewall area. The best soil observed (East Broadway Additions) has a high percentage of failures. This can be attributed to the age of the systems and the small amount of usable soil area.

Person load, sidewall area, and performance are the same for septic tank and cesspool systems in East Broadway Additions. The 35 percent increase in years of service for septic tank systems indicates a more efficient use of the soil by the septic tank-seepage pit system.

Survival Curves.

Mortality-type survival curves for each subdivision are shown in Figures 7 and 8 with the calculations shown in Table 63. These curves interrelate the age at which failure occurs with the total number of failures observed in a given time interval.

The curves for septic tank-seepage pit systems and cesspool systems, shown in Figure 7, clearly show that the septic tank-seepage pit system is more efficient for the soil in East Broadway Additions. The remaining curves, shown in Figure 8, are less conclusive in ranking the soils. Maryvale Parks (Shallow Soil) is easily separated while the three remaining curves are closely grouped. In using the survival curves for evaluation it should be remembered that they do not account for differences in soil absorption area. The mean sidewall area for Belden Courts, Campo Bello, and Griffith Park (representing the poorest soil formation) is 25 to 50 percent greater than that for the other subdivisions. Therefore, the relative position of this curve is favored by the greater amount of usable soil area.

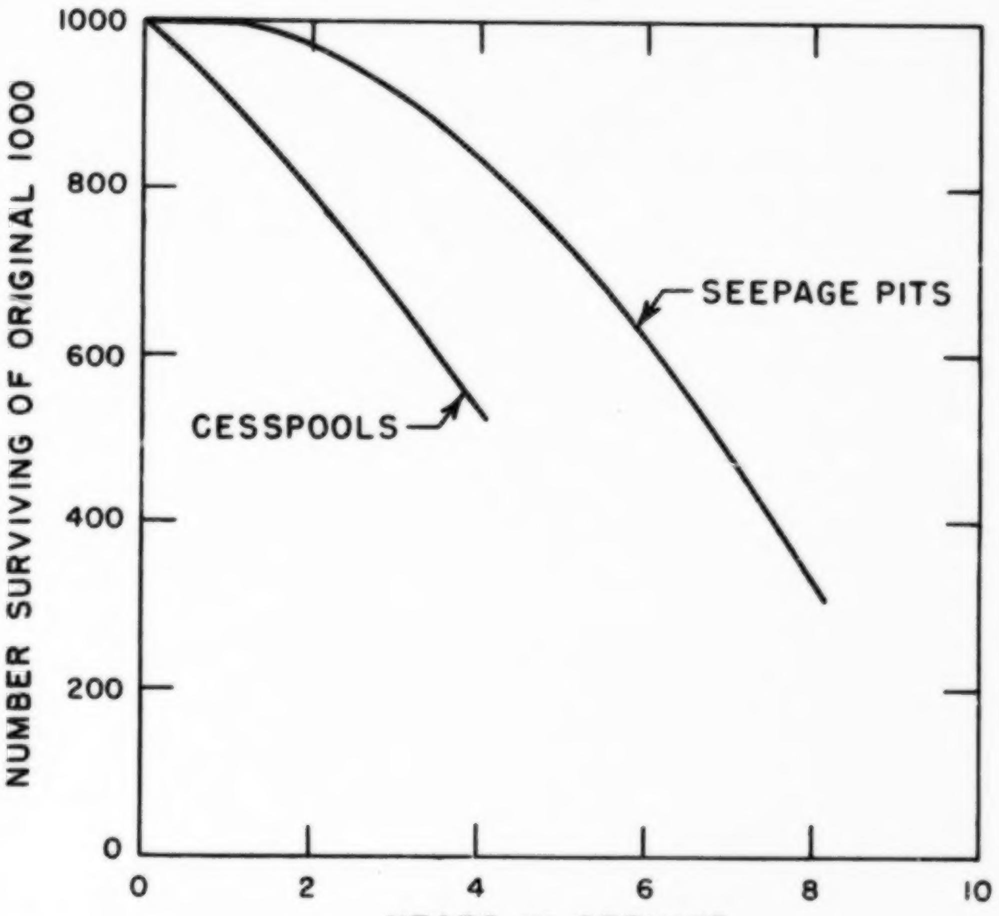
Table 63

Survival Curve Calculations
Maricopa County, Arizona

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
Belden Courts, Campo Bello, and Griffith Park					
0-0.9	98	0	.000	1000	-
1.0-1.9	96	0	.000	1000	-
2.0-2.9	90	3	.033	1000	33
3.0-3.9	65	3	.046	967	44
4.0-4.9	54	5	.092	923	85
5.0-5.9	47	6	.128	838	107
6.0-6.9	26	4	.154	741	112
7.0-7.9	0	0	-	619	-
East Broadway Additions (Septic Tanks)					
0-0.9	37	0	.000	1000	0
1.0-1.9	36	2	.056	1000	56
2.0-2.9	34	2	.059	944	57
3.0-3.9	21	1	.048	887	42
4.0-4.9	17	2	.118	845	100
5.0-5.9	15	2	.133	745	99
6.0-6.9	12	3	.250	646	162
7.0-7.9	8	3	.375	484	182
8.0-8.9	2	0	.000	302	0
9.0-9.9	1	0	.000	302	0
10.0-10.9	1	0	.000	302	0
11.0-11.9	0	0	-	302	-
East Broadway Additions (Cesspools)					
0-0.9	18	2	.111	1000	111
1.0-1.9	16	2	.125	889	111
2.0-2.9	13	2	.154	778	120
3.0-3.9	6	1	.167	658	110
4.0-4.9	0	0	-	548	-

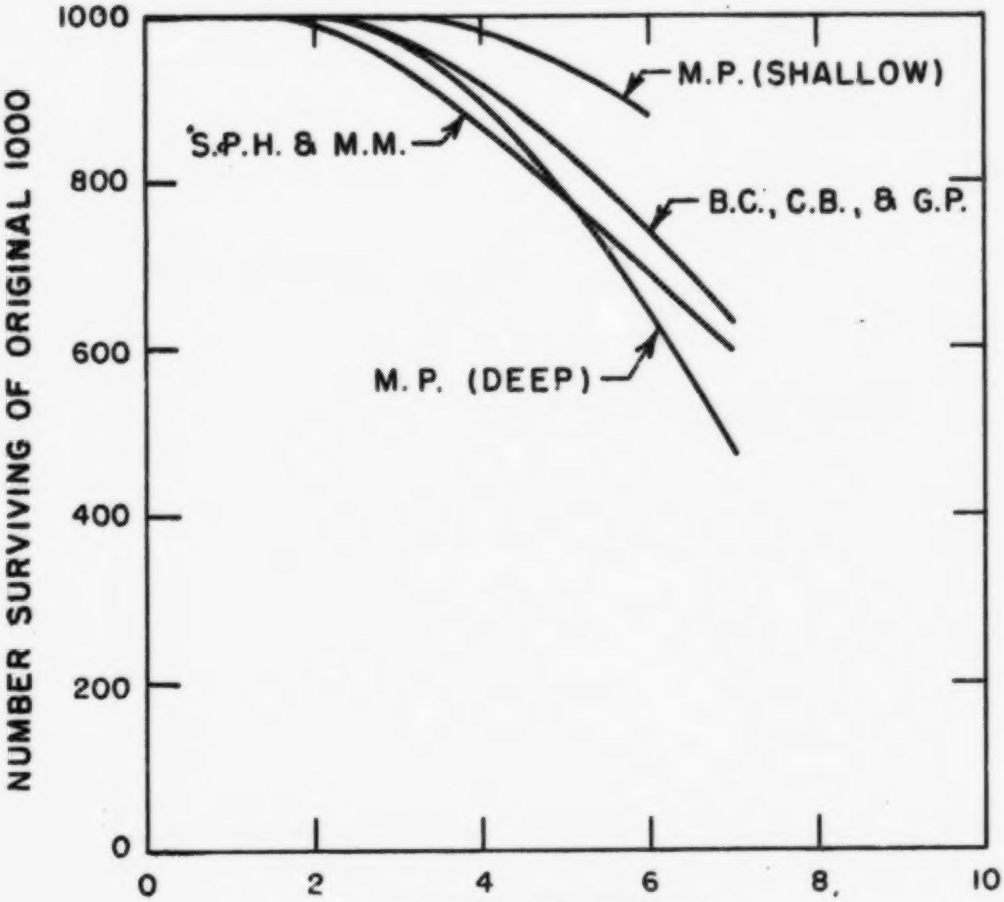
Table 63 (Continued)

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
Maryvale Parks (Shallow Soil)					
0-0.9	35	0	.000	1000	0
1.0-1.9	35	0	.000	1000	0
2.0-2.9	34	0	.000	1000	0
3.0-3.9	34	2	.059	1000	59
4.0-4.9	29	0	.000	941	0
5.0-5.9	3	0	.000	941	0
6.0-6.9	2	0	.000	941	0
7.0-7.9	0	0	-	941	-
Maryvale Parks (Deep Soil)					
0-0.9	23	0	.000	1000	0
1.0-1.9	23	0	.000	1000	0
2.0-2.9	22	0	.000	1000	0
3.0-3.9	22	2	.091	1000	91
4.0-4.9	19	3	.158	909	144
5.0-5.9	17	5	.294	756	225
6.0-6.9	4	0	.000	540	0
7.0-7.9	0	0	-	540	-
Squaw Peak Heights and McLellan Manor					
0-0.9	44	0	.000	1000	-
1.0-1.9	44	0	.000	1000	-
2.0-2.9	44	2	.045	1000	45
3.0-3.9	42	4	.095	955	91
4.0-4.9	30	5	.167	864	144
5.0-5.9	19	1	.053	720	38
6.0-6.9	9	1	.111	682	76
7.0-7.9	-	-	-	606	-



SURVIVAL CURVES
MARICOPA COUNTY, ARIZONA
EAST BROADWAY ADDITIONS

FIGURE 7



SURVIVAL CURVES
MARICOPA COUNTY, ARIZONA

FIGURE 8

INTERPRETATION OF RESULTS

Data presented in the previous sections provide qualitative evaluations of seepage pit performance. Quantitative evaluation of performance depends on establishment of measurable parameters which represent the interrelationship between load, area, and time. A rational mathematical model* has been developed to express this relationship.

Mathematical Formulation.

The mathematical model expresses the relationship between the soil absorption area, A, required for a given period of operation, t, with a loading factor, Q, as:

$$(1) \qquad A = \frac{Q}{kL} + \frac{Q}{L}t$$

where:

k is the rate reaction constant of interface clogging, and

L is the ultimate interface absorption capacity.

Dividing through by the loading factor, Q, produces equation:

$$(2) \qquad \frac{A}{Q} + \frac{1}{kL} + \frac{1}{L}t$$

which is a linear equation with an intercept of $\frac{1}{kL}$ and a slope of $\frac{1}{L}$. This form of the equation can be used to evaluate the field data.

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*Study of Seepage Beds. Report to the Federal Housing Administration, Robert A. Taft Sanitary Engineering Center, December 15, 1960.

Evaluation of Field Data.

Parameters were measured in the field which can be substituted for the parameters A, Q, and t in the model equation. They are:

A (ft^2), seepage pit sidewall area wetted by effluent during a known period of service,

I (ft^3/yr.), water consumption which can be used as an estimate of Q, the loading factor, and

t (yrs.), the period of service during which the area, A, was wetted.

As was stated previously many clothes washer wastes were not discharged to the septic tank system. A correction of 50 gallons per wash load for automatic sequence washers and 25 gallons per wash load for manual sequence washers was deducted from I for these cases. Proportional corrections were made for combinations of automatic and manual sequence washers and for partial discharge of clothes washer wastes to the system.

Area equations, derived from the data tabulated in Table 65, for each of the soil formations are shown in Table 64. The soil formations are ranked in decreasing order according to the slope factor presented in Table 59. Excluding the equation for cesspools in East Broadway Additions, the area required by the design equation increases as the percolation test slope factor decreases. It is of significant interest to note that the design equation for cesspools in East Broadway Additions requires about twice as much area as the equation for septic tank-seepage pit systems.

Table 64

Design Equations and Economic Analyses
Maricopa County, Arizona

Location of Soil Formation	Design Equation	Economic Analysis		
		Optimum Renewal Period (Years)	Optimum Design Area (Ft^2)	Present Value of Cost (Dollars)
East Broadway Add. Septic Tanks	A = 18.2 t	16	291	388
East Broadway Add. Cesspools	A = 38.4 t	11	422	645
Maryvale Parks Shallow Soil	A = 22.0 t	14	314	444
Squaw Peak Heights & McLellan Manor	A = 30.9 t	12	371	553
Maryvale Parks Deep Soil	A = 37.4 t	11	411	633
Belden Courts Campo Bello, & Griffith Park	A = 50.4 t	10	504	798

Economic Analysis.

A procedure* has been developed to derive the most economical design for soil absorption systems. This procedure balances the economic value of initial seepage pit costs against the value of subsequent additions to determine the renewal period which results in the minimum total cost.

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* Harold A. Thomas, James B. Coulter, T. W. Bendixen, and Allan B. Edwards, *Technology and Economics of Household Sewage Disposal Systems.* Journal Water Pollution Control Federation, February 1960.

Information collected during the study indicates the initial cost of a seepage pit is approximately $78.00 plus $0.48 per square foot of absorption area. Seepage pits added at a later date cost approximately 20 percent more than initial installations. Each design equation was evaluated using the above cost data, a 5-percent interest rate, and a 30-year time horizon. The results of this analysis are given in Table 64. The optimum renewal periods range from a low of 10 years to a high of 16 years. The minimum costs shown are closely approximated by renewal periods within two to three years of the optimum.

Table 65

Water Use Data
Maricopa County, Arizona

Belden Courts - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
130	3.5	2.9	189	9,200	48	.021
126	4.0	2.6	176	9,200	52	.020
122	4.2	2.0	211	8,000	38	.026
157	4.5	3.6	233	10,200	44	.023
138	4.6	4.0	197	18,400	94	.011
169	4.8	2.7	249	12,800	51	.019
140	5.4	2.9	205	15,800	28	.013
133	5.4	2.0	188	7,700	49	.024
141	5.5	3.3	198	8,000	40	.025
164	5.5	4.0	235	8,700	37	.027
128	5.6	3.3	192	5,400	28	.036
170	5.8	3.9	253	6,500	26	.039
131	6.0	2.9	196	7,700	39	.025
166	6.0	3.2	231	9,200	40	.025
132	6.3	2.0	183	8,500	46	.022
135	6.4	4.0	171	7,700	45	.022

Belden Courts - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
144	1.6	4.0	107	8,400	78	.013
145	1.9	2.2	75	4,800	64	.016
148	1.9	3.9	122	4,200	34	.029
147	2.0	4.8	215	10,200	47	.021
146	2.2	4.8	152	8,400	55	.018
152	5.0	4.4	235	9,100	39	.026
125	5.1	2.8	183	6,700	37	.027
155	5.2	2.0	184	6,200	34	.029
150	5.4	3.0	203	5,500	27	.037
139	5.4	2.0	188	6,800	36	.028

Table 65 (Continued)

Belden Courts - Successful Systems
(Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
162	5.5	2.0	190	5,700	30	.033
153	5.6	1.7	122	3.700	30	.033
149	5.7	3.0	167	4,000	24	.042
158	5.7	2.1	122	6,800	56	.018
156	5.7	2.9	158	5,800	37	.027
151	5.7	2.0	196	5,700	29	.034
124	5.7	3.3	221	7,500	34	.029
159	5.8	3.0	237	6,100	26	.038
174	5.9	2.9	210	7,500	36	.028
161	5.9	4.4	244	6,200	25	.040
154	6.0	2.0	216	9,100	42	.024
173	6.0	2.4	162	5,900	36	.028
163	6.0	4.8	241	12,000	50	.020
160	6.0	2.6	194	7,000	36	.028
165	6.0	2.0	125	6,900	55	.018
168	6.1	4.4	205	8,500	41	.024
172	6.2	3.3	225	7,600	34	.029
123	6.2	5.0	144	7,000	49	.020
120	6.2	2.3	208	11,200	54	.018
117	6.2	2.0	211	15,200	72	.015
119	6.3	2.0	170	6,500	38	.026
118	6.3	1.7	152	5,400	35	.029
134	6.3	2.7	188	6,800	36	.028
121	6.3	1.7	179	10,700	57	.018
143	6.5	2.8	186	5,300	28	.036
127	6.5	2.1	201	8,300	41	.024
137	6.6	2.3	196	5,600	29	.034
136	6.6	2.0	148	5,900	40	.025

Table 65 (Continued)

Campo Bello - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
247	2.5	5.4	140	14,900	106	.009
238	2.6	4.0	114	10,600	93	.011
253	2.8	7.0	144	14,800	103	.010
254	3.2	3.0	115	7,700	67	.014
241	3.8	4.2	140	12,200	87	.012

Campo Bello - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
252	1.3	4.0	137	4,700	34	.029
245	2.1	6.8	119	8,200	69	.014
237	3.0	2.4	107	7,100	66	.015
249	3.3	4.0	69	15,000	220	.004
244	3.3	4.2	106	7,100	67	.015
240	3.3	3.0	117	10,200	87	.012
239	3.4	3.9	159	8,000	50	.020
243	3.8	4.0	96	7,200	75	.013
246	3.9	4.0	130	4,900	38	.026
248	4.0	3.0	106	2,800	26	.038
242	4.0	4.5	170	7,100	42	.024

Table 65 (Continued)

Griffith Park - All Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
116	2.6	1.9	123	8,500	69	.014
107	2.6	3.0	280	11,500	41	.024
115	2.6	6.0	332	11,500	34	.029
113	2.6	2.0	84	4,800	57	.018
108	2.6	6.2	264	10,400	39	.025
109	2.6	3.5	175	9,600	55	.018
114	2.7	4.0	297	16,300	55	.018
106	2.7	3.4	156	8,700	56	.018
104	2.7	4.0	178	8,900	50	.020
103	2.7	5.1	280	12,500	45	.022
105	2.7	4.3	307	12,500	41	.024
100	2.8	4.9	293	15,300	51	.020
112	2.8	3.0	176	9,100	51	.020
111	2.8	3.2	169	12,300	73	.014
110	2.8	4.8	320	16,500	52	.011
99	2.9	5.0	140	13,100	93	.022
102	2.9	5.0	160	7,200	45	.013
101	3.0	3.0	146	11,200	77	.015

Maryvale Park - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
64	3.3	4.2	81	17,300	214	.005
53	3.4	5.0	199	13,000	57	.018
45	3.7	3.6	165	5,500	33	.030
54	4.7	4.3	203	9,700	48	.021
49	4.9	2.0	161	15,400	96	.010
50	4.9	3.6	172	8,200	48	.021
46	5.2	3.8	181	14,700	36	.012
52	5.4	4.1	198	7,100	28	.028
68	5.5	5.0	199	5,600		.036

Table 65 (Continued)

Maryvale Park - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
44	1.8	4.5	84	10,800	129	.008
67	5.5	5.3	155	9,000	58	.017
419	5.5	2.0	178	14,700	83	.012
59	5.8	3.6	174	5,000	29	.035
60	5.8	3.0	134	8,900	66	.015
66	5.8	3.7	86	7,700	90	.011
42	5.8	5.0	97	10,100	104	.010
43	5.8	4.0	115	5,400	47	.021
61	5.8	4.0	185	9,700	52	.019
58	6.0	3.4	122	6,700	55	.018
55	6.0	6.0	135	10,600	78	.013

Maryvale Park #3 - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
70	3.9	5.0	144	13,900	97	.010

Maryvale Park #3 - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
94	3.8	3.0	50	6,000	120	.008
92	3.9	4.9	48	9,500	198	.005
86	4.0	4.4	102	9,400	92	.011
87	4.0	4.7	68	14,200	209	.005
91	4.0	2.5	78	7,500	110	.009
78	4.0	6.0	112	13,800	81	.012
76	4.1	5.8	114	8,000	70	.014
98	4.1	5.0	42	6,700	160	.006
97	4.1	4.1	53	9,500	179	.006
96	4.1	4.0	127	14,500	114	.009
80	4.2	3.8	103	12,800	124	.008

Table 65 (Continued)

Maryvale Park #3 - Successful Systems (Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
74	4.2	3.0	107	11,000	103	.010
82	4.2	3.0	54	5,000	93	.011
84	4.2	3.2	88	6,400	73	.014
83	4.2	3.1	133	7,300	55	.018
88	4.2	4.5	60	7,300	122	.008
93	4.2	2.0	12	14,600	1,217	.001
90	4.2	4.3	26	7,800	300	.003
85	4.2	4.0	66	8,100	123	.008
73	4.2	3.9	68	9,400	138	.007
95	4.2	3.3	83	9,500	113	.009
77	4.2	3.9	100	10,100	101	.010
75	4.2	3.7	103	14,200	138	.007
89	4.2	5.9	108	11,200	104	.010
79	4.2	3.0	114	8,900	78	.013
69	4.2	4.6	128	7,300	57	.018
72	4.2	4.9	140	11,000	79	.013
71	4.3	3.0	115	10,800	94	.011

McLellan Manor - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
34	2.3	6.0	106	12,100	114	.009
37	3.8	4.0	142	11,000	78	.013

McLellan Manor - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
40	3.0	3.2	000	6,300	-	-
29	3.2	2.0	108	13,100	121	.008
31	3.3	3.4	55	5,200	95	.011

Table 65 (Continued)

McLellan Manor - Successful Systems (Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate $Ft^2/Ft^3 \times Yrs.$
36	3.5	5.0	144	11,300	79	.013
38	3.8	3.0	52	6,900	133	.008
32	3.9	4.0	000	13,700	-	-
30	3.9	3.5	117	9,200	78	.013
33	4.0	2.2	43	11,900	276	.004
41	4.0	2.0	101	9,100	90	.011
39	4.0	4.0	60	5,700	95	.011
35	4.1	6.0	152	8,800	58	.017
Squaw Peak Heights - Failed Systems						
26	3.0	5.0	132	26,200	198	.005
20	3.0	5.0	162	17,700	109	.009
10	3.9	3.0	223	9,800	44	.023
2	4.1	3.0	132	12,800	97	.010
21	4.4	5.0	211	10,700	51	.020
4	4.6	3.5	223	11,200	50	.020
19	4.7	4.0	151	7,600	50	.020
24	4.9	2.8	96	7,800	82	.012
14	5.5	2.8	158	7,700	49	.020
6	6.0	3.0	247	6,700	27	.037
Squaw Peak Heights - Successful Systems						
17	3.3	4.0	35	11,800	338	.003
18	4.8	3.7	142	13,000	92	.011
11	4.9	4.0	128	10,100	79	.013
3	5.0	2.0	90	8,000	89	.011
8	5.0	4.0	218	9,100	42	.024
9	5.2	1.9	143	8,800	61	.016

Table 65 (Continued)

Squaw Peak Heights - Successful Systems (Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
5	5.2	1.6	66	7,700	117	.009
23	5.4	3.3	205	10,200	50	.020
28	5.6	2.0	114	13,200	116	.009
25	5.7	1.3	145	7,900	54	.018
22	5.8	3.8	172	9,900	57	.017
7	5.8	2.0	245	12,200	50	.020
27	6.0	2.0	75	4,700	63	.016
12	6.1	3.3	208	8,800	42	.024
15	6.1	3.9	112	7,000	63	.016
13	6.1	3.5	177	10,300	58	.017
421	6.1	2.0	126	6,200	49	.020
16	6.2	1.5	111	4,600	41	.024
420	6.3	4.0	210	12,700	60	.016
422	6.5	1.3	137	6,100	45	.022

East Broadway Additions (Septic Tanks) - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
186	1.8	8.8	92	21,300	251	.004
198	1.8	6.3	75	13,100	175	.006
204	2.7	2.0	42	5,900	140	.007
202	2.9	5.1	77	6,000	78	.013
194	3.8	5.0	70	7,900	113	.009
200	4.1	4.5	50	8,500	170	.006
189	4.4	4.0	54	10,500	194	.005
201	4.5	3.6	63	8,800	140	.007
184	5.6	2.0	82	5,500	67	.015
177	6.0	2.0	87	11,400	131	.008
182	6.2	2.0	78	7,400	95	.010
183	7.5	2.0	56	5,000	81	.011
190	7.9	4.0	53	14,300	270	.004

Table 65 (Continued)

East Broadway Additions (Septic Tanks) - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate $Ft^2/Ft^3 \times Yrs.$
199	0.9	2.0	74	7,300	98	.010
196	2.2	4.4	20	11,600	580	.002
193	2.3	3.0	51	11,000	216	.005
197	2.4	3.0	51	6,900	135	.007
196	2.6	3.0	63	11,800	187	.005
187	2.7	5.0	88	10,700	122	.008
205	2.7	7.4	88	11,200	127	.008
206	2.8	2.4	97	13,000	134	.007
208	2.8	7.1	97	13,700	141	.007
211	2.9	3.0	41	4,900	120	.008
188	3.1	2.0	67	15,600	233	.004
192	3.2	2.0	78	6,600	85	.012
180	3.2	7.1	103	24,100	234	.004
178	3.8	3.8	103	14,100	137	.007
203	5.2	2.5	34	9,300	274	.004
207	6.2	2.6	84	10,600	126	.008
179	7.3	3.0	64	5,400	84	.012
181	7.4	3.7	98	7,600	78	.013
191	7.5	2.0	27	3,800	141	.007
175	10.0	5.1	120	6,900	58	.017

Table 65 (Continued)

East Broadway Additions (Cesspools) - Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use $Ft^3/Yr.$*	Application Rate $Ft^3/Ft^2/Yr.$	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
232	0.7	3.0	56	7,100	126	.008
223	0.9	6.0	74	3,500	47	.021
219	1.6	2.0	68	7,100	104	.010
222	2.2	5.1	64	5,400	84	.012
227	2.6	4.0	119	10,400	87	.011
226	3.0	3.8	60	4,600	77	.013
230	3.2	3.0	98	7,100	72	.014
217	7.5	2.0	76	9,800	129	.008
East Broadway Additions (Cesspools) - Successful Systems						
221	1.8	7.1	101	11,000	113	.008
220	2.6	4.7	79	11,600	147	.007
224	2.7	3.0	142	13,000	91	.011
218	2.8	2.0	39	3,600	92	.011
228	2.9	6.0	79	8,200	104	.010
229	3.0	3.0	55	5,400	97	.010
215	3.1	2.0	50	4,700	94	.011
225	3.1	2.0	76	8,200	108	.009
231	3.4	2.5	135	10,900	81	.012

*Derived from average winter (December, January, and February) use.

SECTION VIII

NUECES COUNTY,

TEXAS

Nueces County, Texas

SUMMARY

Nueces County is located on the Gulf of Mexico 200 miles southwest of Houston. Metropolitan Corpus Christi accounts for 80 percent of the county population of 222,000 shown in the 1960 census. The climate is intermediate between semiarid and subtropical. Humidity is relatively high, and freezing temperatures occur only occasionally in January and February.

Septic tank regulations are enforced by the Sanitation Division of the Nueces County Health Department. Present regulations permit the use of seepage pits only in areas where there is no danger of contaminating a potable water supply. The study was confined to an area where seepage pits had been installed under regulations existing from 1947 to 1950.

Design features in Nueces County provided the opportunity to observe seepage pits preceded by secondary treatment. The typical system consisted of a 500-gallon, one-compartment septic tank; a 15-cubic yard, subsurface rock filter; and a gravel-filled seepage pit. Some systems were not equipped with the subsurface rock filter. However, the poor performance observed with both types masked any possible effect of the secondary treatment.

A total of 56 septic tank systems, 41 with and 15 without subsurface rock filters, was inspected in a subdivision located on a uniform soil formation. Soil investigations were conducted at three sites, and one operating seepage pit was excavated to verify tentative conclusions resulting from general survey information. Two procedures (a gross performance table and survival curves) are used to evaluate the observed performance.

CONCLUSIONS

The following conclusions apply to the use of seepage pits under the conditions of loading, design, and construction observed in Nueces County, Texas:

1. The septic tank-seepage pit system as designed and constructed does not provide a suitable method for disposal of effluent. Very high rates of failure were observed.

2. A sludge mat developed on the surface of the gravel used to backfill seepage pits in Ebony Acres subdivision, and resulted in premature failure of the septic tank systems in many cases.

3. Small and poorly graded gravel backfill appeared to be the limiting factor in the operation of seepage pits in this area.

GENERAL INFORMATION

Nueces County is located on the Gulf of Mexico 150 miles north of the Mexican border and 200 miles southwest of Houston. Corpus Christi, the County's major City, is served by excellent deep water facilities making it the major trade center for eight surrounding counties.

The population of Nueces County has mushroomed from a meager 25,000 in 1920 to 222,000 in 1960. Metropolitan Corpus Christi includes 80 percent of the total County population.

Geology.

The coastal region around Corpus Christi is on the alluvial deposits of the Nueces River delta. The surface formation is the Beaumont clay which covers the area to a depth of 8 to 20 feet. The clay cover is continuous except for the most recent river channels and beach areas which are identified by sandy, permeable soil at the surface. The Beaumont clay is underlain by a deep sandy clay to clay formation with lenticular strata of medium to fine sands. The uppermost stratum of sand is relatively continuous throughout the metropolitan area. This stratum, ranging in thickness from 5 to 24 feet, is encountered directly beneath the Beaumont clay.

Soils and Topography.

The soil mantle, developed from the Beaumont clay, is relatively shallow and poorly drained.

Except for the downtown section, metropolitan Corpus Christi is situated on a bluff dipping gently from north to south. The highest elevation is approximately 45 feet in the northwest area along State Highway 9. From this point the slope is gradual to the south where the elevation is only a few feet above sea level in the Flour Bluff district. Surface drainage is generally poor and runoff is channeled into ditches when storm sewers are not available.

Ground Water.

In general the ground water within the metropolitan area is not potable. The water table is approximately at sea level; therefore, the depth to ground water ranges from a few feet in Flour Bluff to over 40 feet in the northwest area.

Climate.

The climate of Nueces County is intermediate between the subtropical regions to the northeast and the semiarid regions to the west and southwest. The mean annual rainfall is 26 inches and the potential evapotranspiration is 45 inches.

Mean temperatures range from a low of 50 degrees during the winter to a high of 82 degrees in the summer. There is an average of 5 days a year when the low temperature drops below 32 degrees, and an average of 100 days with the maximum over 90 degrees. Relative humidity is consistently high because of the proximity of Corpus Christi Bay. There is a daily fluctuation from a high of 90 percent at 6:00 a.m. to a low of about 60 percent during the afternoon. Climatological data which may affect the operation of septic tank systems are summarized in Table 66.

Health Department Organization and Septic Tank Practice.

Septic tank system control constitutes a small fraction of the Health Department's total program. It is handled by the chief sanitarian and the engineer in charge of the Sanitation Division.

At present seepage pits are not accepted for disposal of septic tank effluent. In the period from 1947 to 1950 when seepage pits were commonly installed an accurate plan of each system including location, construction details, and dimensions, was filed with the Health Department. The seepage pit design required a minimum of 75 square feet of wall area per bedroom,in fine sand. All systems installed since early 1948 have a subsurface rock filter preceding the seepage pit.

Review of Health Department Records.

A situation similar to that which we encountered in other locations regarding health department records also exists in Nueces County. The complaints in the Health Department files are not representative of the sewage system failures encountered in the field. As an example, Ebony Acres subdivision has had 100 percent failure of the septic tank systems installed in 1948 and 1949. A partial review of the Health Department files showed only four complaints of exposed sewage for this subdivision from 1953 through 1958.

Table 66

Summary of Climatological Data
Nueces County, Texas*

Temperature, Precipitation, and Sunshine for Years of Record from 1905 to 1959

Season	Temperature, °F			Precipitation, Inches			Percent of Possible Sunshine
	Mean	Mean Maximum	Mean Minimum	Mean Total	Driest Year	Wettest Year	
Annual	71	78	64	26.2	5.4	43.9	69
Winter (Dec.Jan.Feb.)	58	66	51	4.7	0.2	19.9	53
Summer (Jun.Jul.Aug.)	82	89	76	6.3	1.1	21.8	92

Temperature and Precipitation for Years Preceding and During Survey

Dates	Mean Temperature, °F			Mean Precipitation, Inches		
	Annual	Winter	Summer	Annual	Winter	Summer
1949-58	72	60	84	24.8	4.1	5.1
1954-58	72	60	84	26.0	5.5	3.7
Apr.'58-Mar.'59	71	55	85	32.2	10.2	3.2

*Weather Bureau Station at Cliff Maus Field, Corpus Christi, Texas.

RESULTS OF FIELD STUDIES

Field studies were conducted in Nueces County from early February through April in 1959. The study provided an opportunity to evaluate the use of rock-filled pits and a subsurface rock filter installed between the septic tank and seepage pit. The work that was completed in Nueces County is summarized in Table 67.

Table 67

Summary of Field Activities
Nueces County, Texas

System Type	General Surveys	Detailed Studies	Total
Ebony Acres With Rock Filters	39	2	41
Ebony Acres Without Rock Filters	14	1	15
Total	53	3	56

Subdivision and Soil Descriptions.

Ebony Acres subdivision was developed over a relatively short period from 1948 to 1950. The basic home is a 4-room, 2-bedroom, frame house located on a 10,000 square-foot lot. Many homeowners have subsequently added additional bedrooms to accommodate growing families. In general, yard maintenance is good with well-established lawns and frequent plantings of shrubbery and trees. Surface drainage is poor, and surface ponding occurs frequently in many yards.

The soil in this subdivision is a clay developed from the Beaumont formation which in this area ranges from 10 to 20 feet thick. It is underlain by a heterogeneous mixture of lenticular strata. The texture of these strata ranges from medium sand to clay with an average of approximately six feet of clean sand strata being penetrated before reaching 30 feet. Soil parameters measured at the three detailed study sites are summarized on Table 68.

Construction and Loading.

A unique construction practice was employed in Nueces County. At many installations effluent from the septic tank passed through a subsurface rock filter before entering the seepage pit. The rock filter was constructed by excavating a rectangular pit (6 by 15 feet) about 6 feet deep in the Beaumont clay. This pit was backfilled with gravel, a single collector line was placed at the bottom, and two distributor lines were placed near the top of the gravel. This construction practice was used at 41 of the general survey sites.

The seepage pit was a rock-filled type ranging from 12.3 to 41.0 feet deep. All pits were 2.2 feet in diameter and the rock backfill was stopped about 10 feet below the ground surface. The pit was lined with concrete pipe from the rock backfill to the ground surface. The textural gradation of the backfill was variable with as much as 25 percent of the sample passing a one-half inch screen in some cases. Pertinent seepage pit construction data are summarized in Table 69.

Loading factors which may influence the operation of the septic tank system are also summarized in Table 69. The median number of persons is approximately the same for both types of systems, while water use is somewhat

Table 68

Detailed Soil Investigation Results
Nueces County, Texas

Number of Tests	D_{10} mm*		Percolation Rate**		Slope Factor***		Visual Permeability Rating****	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
3	.091	.080-.111	1.08	.556-1.61	.078	.072-.085	2.3	2.0-2.6

*Percentile by weight. D_{10} is the particle diameter at which 10 percent of the sample will pass.

**Percolation rate in gal./ft^2/min. at a head equal to the depth of ponding in the existing seepage pit for the slowest percolation run.

***A plot of $\frac{1}{H}$ (head in ft.) vs. Σt (hrs.) for the percolation test produces a straight line with slope m. The slope factor equals $m \frac{D}{4}$ where D equals the pit diameter.

****Average value weighted for thickness of strata and based on a scale where: 1 = excellent, 2 = good, 3 = fair, and 4 = poor.

Table 69

Construction and Loading Data
Nueces County, Texas

Item		With Rock Filters	Without Rock Filters
Number of Observations		41	15
System Age, Yrs.			
	Median	9.9	10.7
	Range	8.3-10.6	5.7-10.9
Person Load, No.			
	Median	3.1	3.0
	Range	2.0-6.0	2.0-5.0
Water Use, $Ft^3/Yr. \times 10^{-3}$ (Dec.Jan.Feb.)			
	Median	7.8	6.6
	Range	4.5-13.0	5.2-11.4
Septic Tank Cap., Gals.			
	Median Range	All 500	All 500
Pit Diameter, Ft.			
	Median Range	All 2.2	All 2.2
Pit Depth, Ft.			
	Median	22	26
	Range	15-31	12-41
Pit Sidewall Area, Ft^2			
	Median	150	200
	Range	97-264	71-276

greater for the "with rock filter" systems. Many modern household appliances may contribute to septic tank loading. Data for some of these are presented in Table 70. The percentage of homes with a food waste grinder, dishwasher, or water softener was negligible. Several homes in the "without rock filter" group were not equipped with a clothes washer, while all of those in the "with rock filter" group were equipped with a clothes washer. At nearly all of the homes clothes washer waste was not discharged to the septic tank systems.

Table 70

Household Appliances
Nueces County, Texas

Appliance	Percentage of Homes with Appliance	
	With Rock Filters	Without Rock Filters
Food Waste Grinder	5	0
Dishwasher	2	0
Water Softener	0	0
Clothes Washer	100	79
Manual	30	14
Automatic	58	50
History of Both	12	15

Gross Performance and Survival Curves.

The general survey data can be employed to make a qualitative evaluation of the effect of the subsurface rock filter on performance. Data for this evaluation are summarized in Table 71. Qualitatively the "with rock filter" systems have performed more satisfactorily. They have less provided area and a greater person load, yet they have given a somewhat longer period of satisfactory service.

Table 71

Gross Performance
Nueces County, Texas

Type of System	Years of Service Mean	Years of Service Range	Mean Persons (No.)	Mean Sidewall Area (Ft^2)	No. of Obs.	Performance No. Failed	Performance No. Satisfactory	Performance Percent Failed
With Rock Filters	4.2	0.8-9.5	3.6	163	41	41	0	100
Without Rock Filters	3.7	1.0-10.6	3.0	206	15	14	1	93

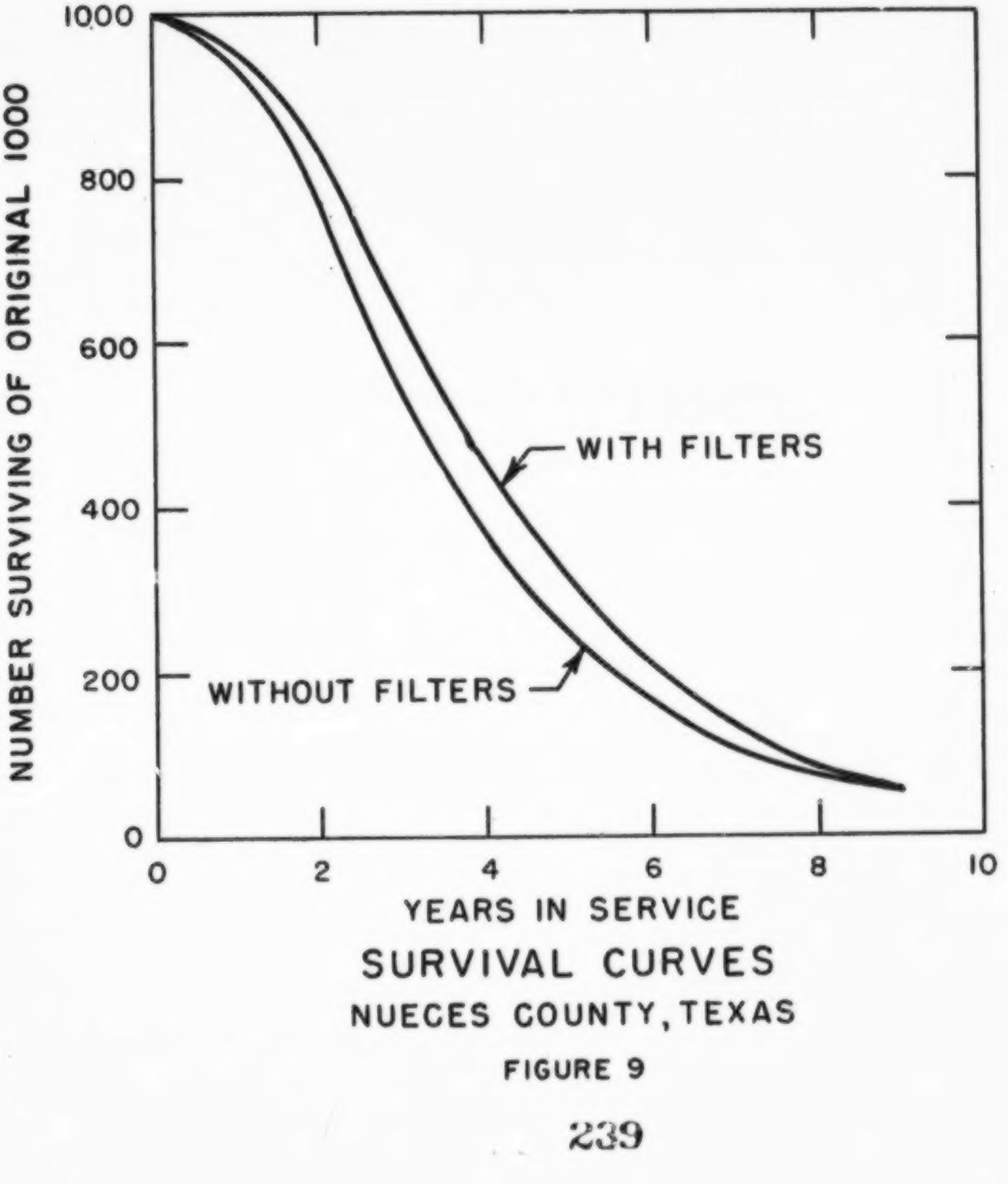
The mortality-type survival curves shown in Figure 9 provide an alternate method of qualitatively evaluating performance. This method relates failure rate to the relative age of the system. The "with rock filter" systems also exhibit a slight advantage with this method of evaluation despite the biases in provided area and person load which tend to favor the "without rock filter" systems. Calculations for the survival curves are presented in Table 72.

Both of these qualitative evaluations are affected to an unknown degree by a major construction fault. Information obtained from homeowners and general survey data showed that many seepage pits could be reactivated by disturbing the uppermost two or three feet of the gravel backfill. Complete excavation of the seepage pit at one of these sites proved that the seepage pit failure was not caused by soil failure. In this case the use of undersized gravel had resulted in the formation of a sludge mat on the surface of the gravel backfill. This mat prevented effluent from passing downward through the gravel at a rate equal to or exceeding the average daily sewage flow.

Table 72

Survival Curve Calculations
Nueces County, Texas

Age of System	Number Reaching Age	Number Failed	q_x	l_x	d_x
Ebony Acres #3 (With Rock Filters)					
0-0.9	41	3	.075	1000	75
1.0-1.9	38	3	.081	925	75
2.0-2.9	35	8	.228	850	194
3.0-3.9	27	7	.259	656	170
4.0-4.9	20	6	.300	486	146
5.0-5.9	14	4	.286	340	97
6.0-6.9	10	3	.300	243	73
7.0-7.9	7	3	.429	170	73
8.0-8.9	4	3	.750	97	73
9.0-9.9	1	1	1.000	24	24
10.0-10.9	0	0	-	0	-
Ebony Acres #3 (Without Rock Filters)					
0-0.9	15	0	.000	1000	-
1.0-1.9	15	3	.200	1000	200
2.0-2.9	12	5	.417	800	334
3.0-3.9	7	4	.571	466	266
4.0-4.9	3	0	.000	200	0
5.0-5.9	3	0	.000	200	0
6.0-6.9	3	1	.333	200	100
7.0-7.9	2	0	.000	100	0
8.0-8.9	2	1	.500	100	50
9.0-9.9	1	0	.000	50	0
10.0-10.9	1	0	.000	50	0
11.0-11.9	0	0	-	50	-



SURVIVAL CURVES
NUECES COUNTY, TEXAS
FIGURE 9

INTERPRETATION OF RESULTS

The field data cannot be used to establish area requirements for the soil formation in Ebony Acres. The field investigations showed that many pit failures in this subdivision could be traced to faulty construction practice. Therefore, the areal load relationships observed in this subdivision are not necessarily a function of the soil absorption capacity. Use of these areal load data in the mathematical model would produce a design equation related to the combined effect of construction malpractice and soil absorption capacity.

Table 73

Water Use Data
Nueces County, Texas

Ebony Acres #3 (With Rock Filters) - All Failed Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
453	0.8	4.0	150	8,200	54	.018
475	0.9	4.0	122	6,100	50	.020
444	0.9	5.0	135	7,800	58	.017
454	1.0	-	191	6,000	31	.032
456	1.0	5.2	137	4,500	32	.030
445	1.8	2.7	136	8,400	62	.016
479	2.0	3.0	207	8,300	40	.025
429	2.0	4.0	128	9,000	70	.014
482	2.0	-	193	-	-	-
437	2.0	3.0	163	6,000	36	.027
440	2.0	6.0	136	6,600	48	.021
477	2.5	2.0	147	8,200	56	.018
427	2.8	4.0	117	9,000	76	.013
426	3.0	3.0	143	7,600	53	.019
443	3.0	5.1	157	9,400	60	.017
476	3.5	2.8	148	8,400	56	.018
448	3.6	5.2	211	6,800	32	.031
436	3.7	3.0	144	5,300	36	.027
450	3.7	3.4	140	8,100	58	.017
435	3.8	2.0	264	9,900	38	.027
441	4.0	3.0	146	7,400	50	.020
480	4.0	3.0	207	7,200	34	.029

Table 73 (Continued)

Ebony Acres #3 (With Rock Filters) - All Failed Systems (Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
434	4.5	2.0	264	10,000	38	.026
438	4.5	2.7	131	8,600	66	.015
442	4.5	3.9	152	9,700	64	.016
452	4.5	6.0	198	12,700	64	.016
439	5.0	3.7	122	7,400	60	.016
481	5.0	3.0	200	-	-	-
431	5.3	3.1	117	7,600	65	.015
425	5.7	3.0	150	7,300	48	.020
478	6.0	4.0	144	11,700	81	.012
449	6.0	-	204	7,800	38	.026
430	6.4	5.0	235	9,700	41	.024
451	7.2	3.7	211	7,400	35	.028
474	7.6	3.0	169	13,000	76	.013
433	7.6	3.6	152	6,100	40	.025
428	8.2	3.1	139	7,400	53	.019
447	8.3	2.2	136	4,700	34	.029
446	8.5	3.0	170	8,600	50	.020
432	9.5	2.0	97	7,100	73	.014
Ebony Acres #3 (Without Rock Filters) - Failed Systems						
462	1.0	3.0	177	6,000	34	.030
471	1.7	2.2	158	-	-	-
466	1.8	4.0	**193	6,600	34	.029
461	2.0	3.3	**238	11,400	48	.021

Table 73 (Continued)

Ebony Acres #3 (Without Rock Filters) - Failed Systems (Continued)

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
469	2.5	2.0	259	5,400	20	.048
467	2.8	3.0	-	7,800	-	-
463	2.8	3.0	184	5,200	28	.035
464	2.8	4.0	276	5,500	20	.050
465	3.0	2.7	164	8,700	53	.019
472	3.0	5.0	71	-	-	-
484	3.0	2.0	**276	5,800	21	.048
460	3.4	2.0	148	10,400	70	.014
470	6.8	3.5	265	11,400	43	.023
468	8.0	3.7	**270	5,800	22	.046

Ebony Acres #3 (Without Rock Filters) - Successful Systems

Reference No.	Time in Svc.(Yrs.)	Persons (No.)	Sidewall Area(Ft^2)	Water Use Ft^3/Yr.*	Application Rate Ft^3/Ft^2/Yr.	Reciprocal Application Rate Ft^2/Ft^3 x Yrs.
483	10.6	2.0	**207	6,500	31	.032

*Derived from average winter (December, January, and February) use.

**These areas were obtained from the Health Department records.

Date________________ Reported by________________Ref No.____________

General Data

1. Address___________________________________Age of home________yrs.

2. Name______________________________________Age in residence___yrs.

3. Type of System: Pit____, Bed____, Trench______, Other________

4. Has system failed____________Age___ ___
(Conclusion from question No. 18)

5. Will owner permit digging up of system______________

6. Size of home: Rooms__________Bedrooms______Age of Children____________

7. Size of family: Adults________Children__ ______Total___________
(If size has varied, estimate average)

8. Size of lot: Front___ft. Rear____ft. Depth____ft. Area____sq.ft.

9. Water use: City___(Account No.______) Private well__Cistern__Other___
(Attach water use records on separate sheet)

10. Fixtures discharging to system (note any by-passing tank)

Kitchen: Sink________, Food Waste Grinder_______, Dishwasher__________

Bathroom: Toilets____,Wash Basins ___,Tubs___,Showers___,Combinations__

Laundry: Trays____,Conv.Washer_____,Auto.Washer______ Drier________

Make and Model of Washer___________Date use started________

Make and Model of Drier____________Date use started________

Water softener_________, Give type & regeneration details

Other:

11. Household Habits

Laundry: No. of loads per week_________

Soap____Detergent___Brand________Boxes/month______ _____size

Kitchen:

Soap____Detergent___Brand________Boxes/month______ _____size

Septic Tank Data

12. Date installed________No. of times cleaned_______Date last cleaned______

13. Type: Capacity____gals., Shape________,Compartments______Material________
(Attach sketch of tank, if available)

14. Have chemical "cleaners" or "starters" been used?

Brand________________Date______________

Soil Absorption System Data

15. Date installed__________(If not original system explain & date changes)

16. Provide lot & system layout sketch and profile section on back of sheet sufficient to establish general topography, location of buildings, drives, walks, shrubs, trees, and disposal system components.

17. Vegetation: (Note locations on sketch)

Bare_______Lawn______Shrubs_______Trees______Other_______________

18. Has system created a nuisance or failed to function properly_________
Describe: (Utilize all sources of information, i.e., owner, observation, records, etc.)

19. System dimensions: (provide detailed sketches on back of sheet)

Dia. of excavation__________ft., Dia. of lining_____________ft

Type of lining_________________, Depth of pit below inlet________ft.

Depth of inlet below G.S._______Thickness of annular gravel fill____ft.

Size gravel___________to__________inches.

20. Depth of effluent ponded in pit_____________ft.

21. Soils Data:

(a) Attach log of test pit with description and sieve analysis of each stratum to a depth of four feet below bottom of seepage pit. Analysis to include nos. 10, 18, 35, 60, 120 and 230 sieve sizes coarser sieves to be used as needed.

(b) Attach percolation test data.